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DIGITAL SIMULATION FOR DESIGN OF A DISTURBANCE ABSORBING CONTROLLER FOR A FOURTH-ORDER PLANT WITH SECOND-ORDER DISTURBANCE AT INPUT

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12 May 1980

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A simulation is presented which utilizes user-input plant and state observer pole placement data to generate a disturbance-absorbing control component, u_c, which will cancel the effects of a disturbance which is entering the system at the plant input.

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CONTENTS

I. INTRODUCTION

The Disturbance Accommodating Controller (DAC) design method was developed by Dr. C. D. Johnson (References 1-5) of the University of Alabama in Huntsville. This method uses a combination of waveform-mode disturbance modeling and state-variable control techniques and permits three primary modes of disturbance accommodation: (1) cancellation (absorption) of disturbance effects, (2) minimization of disturbance effects and, (3) utilization of disturbance effects as an aid in accomplishing the primary control task. This report, and the digital simulation presented herein, will deal with the methods associated with the first mode, i.e., absorption.

The plant considered is one which can be described by state equations of the Form

$$\begin{aligned} \dot{\underline{x}} &= \underline{A}\,\underline{x} + \underline{B}\,\underline{u} + \underline{F}\,\underline{w} \\ \underline{y} &= \underline{C}\,\underline{x} + \underline{E}\,\underline{u} + \underline{G}\,\underline{w} \end{aligned} \tag{1}$$

where

$\underline{x}$ is the plant state vector

$\underline{u}$ is the plant control input vector

$\underline{w}$ is the vector of external disturbances acting on the plant

$\underline{y}$ is the system output vector, and

$\underline{A}$, $\underline{B}$, $\underline{F}$, $\underline{C}$, $\underline{E}$, $\underline{G}$ are appropriate size, known matrices which are not necessarily constant.

The disturbances considered are assumed to be described by the following general set of linear disturbance state equations:

$$\begin{aligned} \underline{w} &= \underline{H}\,\underline{z} + \underline{L}\,\underline{x} \\ \dot{\underline{z}} &= \underline{D}\,\underline{z} + \underline{M}\,\underline{x} + \underline{\sigma} \end{aligned} \tag{2}$$

where

$\underline{z}$ is the disturbance "state" vector

$\underline{\sigma}$ is a sequence of randomly arriving vector impulses, and

$\underline{D}$, $\underline{H}$, $\underline{L}$, $\underline{M}$, are known, time-invarient matrices.

Since neither a complete set of plant state variables nor the various components of the disturbance are available for direct on-line measurement in most practical applications, the DAC is restricted to operate only on information in the available on-line measurements of the system outputs and

commands and on any disturbance components which may actually be available for direct measurement. Since the plant and disturbance states ($\underline{x}$, $\underline{z}$) are required for a practical DAC implementation, the necessary data, if not available, must be generated via use of state reconstructors (observers) operating on real-time system outputs $\underline{y}$ and control inputs $\underline{u}$.

A full-dimensional observer which can be used to generate the plant and disturbance state estimates ($\hat{\underline{x}}$, $\hat{\underline{z}}$) for the equations of the form (1) and (2) is given in Reference 2 as

$$\begin{pmatrix} \dot{\hat{\underline{x}}} \\ \dot{\hat{\underline{z}}} \end{pmatrix} = \left[\begin{array}{c|c} \underline{A} + \underline{F}\,\underline{L} + \underline{K}_1 \; (C + \underline{G}\,\underline{L}) & [\underline{F} + \underline{K}_1\,\underline{G}] \;\; \underline{H} \\ \hline \underline{M} + \underline{K}_2 \; (\underline{C} + \underline{G}\,\underline{L}) & \underline{D} + \underline{K}_2\,\underline{G}\,\underline{H} \end{array}\right] \begin{pmatrix} \hat{\underline{x}} \\ \hline \hat{\underline{z}} \end{pmatrix}$$

$$- \begin{bmatrix} \underline{K}_1 \\ \\ \underline{K}_2 \end{bmatrix} \underline{y}(t) + \begin{bmatrix} \underline{B} + \underline{K}_1\underline{E} \\ \\ \underline{K}_2\,\underline{E} \end{bmatrix} \underline{u}(t) \tag{3}$$

where

$\underline{K}_1$, $\underline{K}_2$ are gain matrices to be designed, and

$\underline{A}$, $\underline{F}$, $\underline{L}$, $\underline{C}$, $\underline{G}$, $\underline{H}$, $\underline{D}$, $\underline{M}$ are as previously defined.

For acceptable observer performance, the real-time estimation errors

$$\begin{aligned} \underline{\varepsilon}_x &= \underline{x} - \hat{\underline{x}} \\ \underline{\varepsilon}_z &= \underline{z} - \hat{\underline{z}} \end{aligned} \tag{4}$$

must settle to zero rapidly in comparison to system settling times where $\underline{\varepsilon}_x$ and $\underline{\varepsilon}_z$ dynamics are governed by

$$\begin{pmatrix} \dot{\underline{\varepsilon}}_x \\ \dot{\underline{\varepsilon}}_z \end{pmatrix} = \left[\begin{array}{c|c} \underline{A} + \underline{F}\,\underline{L} + \underline{K}_1 \; (\underline{C} + \underline{G}\,\underline{L}) & [\underline{F} + \underline{K}_1\,\underline{G}] \;\; \underline{H} \\ \hline \underline{M} + \underline{K}_2 \; (\underline{C} + \underline{G}\,\underline{L}) & \underline{D} + \underline{K}_2\,\underline{G}\,\underline{H} \end{array}\right] \begin{pmatrix} \underline{\varepsilon}_x \\ \underline{\varepsilon}_z \end{pmatrix} + \begin{pmatrix} \underline{0} \\ \hline \sigma(t) \end{pmatrix} . \tag{5}$$

II. PLANT MODEL

This simulation will model a fourth-order plant expressed in the form shown in Figure 1.

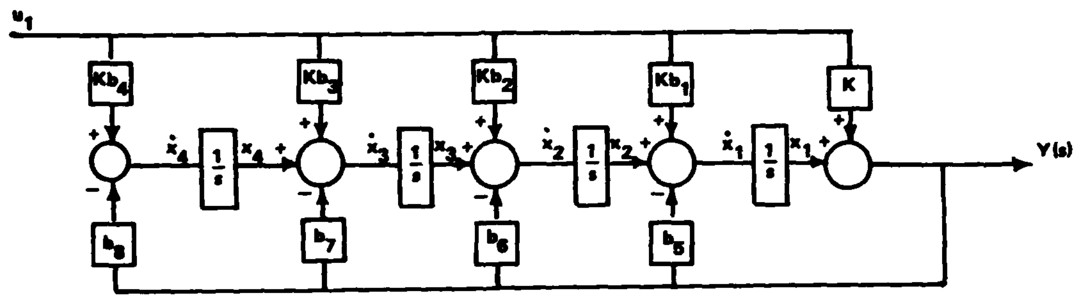

Figure 1. Plant model.

The transfer function across the plant is

$$\frac{y(s)}{u_1(s)} = \frac{K\left[S^4 + b_1 s^3 + b_2 s^2 + b_3 s + b_4\right]}{s^4 + b_5 s^3 + b_6 s^2 + b_7 s + b_8}$$

and this can be diagrammed as shown in Figure 2. As can be seen from Figure 2,

$$\begin{aligned}
\dot{x}_1 &= x_2 + Kb_1 u_1 - b_5 y \\
\dot{x}_2 &= x_3 + Kb_2 u_1 - b_6 y \\
\dot{x}_3 &= x_4 + Kb_3 u_1 - b_7 y \qquad\qquad (6) \\
\dot{x}_4 &= Kb_4 u_1 - b_8 y \\
y &= x_1 + Ku_1 \quad .
\end{aligned}$$

For purposes of DAC design, equations (6) need to be expressed as functions of $\underline{x}$, $\underline{u}$, and $\underline{w}$. Therefore, since

$$u_1 = u + w, \text{ then}$$

$$\begin{aligned}
y &= x_1 + K(u + w) \\
\dot{x}_1 &= -b_5 x_1 + x_2 + K(u + w)\ (b_1 - b_5) \\
\dot{x}_2 &= -b_6 x_1 + x_3 + K(u + w)\ (b_2 - b_6) \qquad (7) \\
\dot{x}_3 &= -b_7 x_1 + x_4 + K(u + w)\ (b_3 - b_7) \\
\dot{x}_4 &= -b_8 x_1 + K(u + w)\ (b_4 - b_8)
\end{aligned}$$

In matrix form, Equations (7) can be written as

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{pmatrix} = \begin{bmatrix} -b_5 & 1 & 0 & 0 \\ -b_6 & 0 & 1 & 0 \\ -b_7 & 0 & 0 & 1 \\ -b_8 & 0 & 0 & 0 \end{bmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} + K \begin{bmatrix} b_1 - b_5 \\ b_2 - b_6 \\ b_3 - b_7 \\ b_4 - b_8 \end{bmatrix} \underline{u} + K \begin{bmatrix} b_1 - b_5 \\ b_2 - b_6 \\ b_3 - b_7 \\ b_4 - b_8 \end{bmatrix} \underline{w} \qquad (8)$$

$$\underline{y} = \begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} + [K]\ \underline{u} + [K]\ \underline{w} \quad . \qquad (9)$$

These correspond to Equations (1).

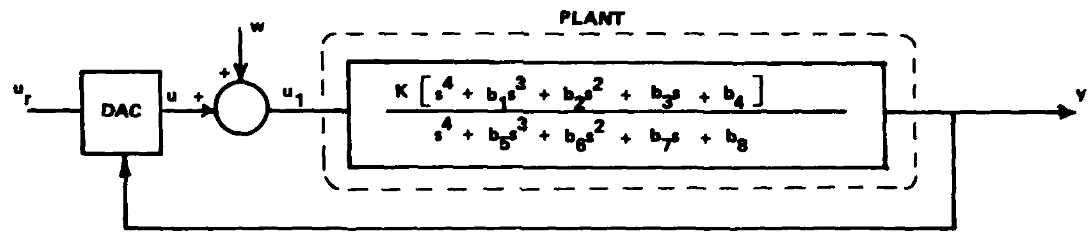

Figure 2. Plant state diagram.

III. DISTURBANCE MODEL

The general set of equations describing the disturbances were given in Equations (2). In this report, it is assumed that the disturbance is not dependent on the plant state, i.e., $\underline{L} \equiv \underline{M} \equiv \underline{0}$. Therefore, the disturbance modeled in the subroutine is

$$\begin{aligned} \underline{w} &= \underline{H}\,\underline{z} \\ \dot{\underline{z}} &= \underline{D}\,\underline{z} + \underline{\sigma}(t) \end{aligned} \qquad (10)$$

and it has been restricted to be a second-order model which can be represented as

$$\underline{w} = \underline{H}\,\underline{z} = (h_1\ h_2)\begin{pmatrix} z_1 \\ z_2 \end{pmatrix} \qquad (11)$$

$$\dot{\underline{z}} = \underline{D}\,\underline{z} + \underline{\sigma} = \begin{bmatrix} d_1 & d_3 \\ d_2 & d_4 \end{bmatrix}\begin{pmatrix} z_1 \\ z_2 \end{pmatrix} + \underline{\sigma} \ . \qquad (12)$$

IV. DISTURBANCE ABSORBER CONTROL

For the complete absorption mode of DAC design, the object is to obtain a control vector which will completely cancel out the effects of the disturbance input. First, however, it must be verified that such a control exists for the particular case being considered.

It has been shown (Reference 1) that such a control vector, $\underline{u}_c$, will exist if, and only if,

$$\underline{F} \equiv \underline{B}\,\underline{\Gamma}$$

for some $\underline{\Gamma}$. With the disturbance summed at the plant input, as shown in Figure 1, we can see from the representation in Equation (8) that $\underline{F} \doteq \underline{B}\,\underline{\Gamma}$ for $\underline{\Gamma} = [1]$. Therefore, for this plant-disturbance model, $\underline{u}_c$ exists and is $\underline{u}_c = -\underline{\Gamma}\,\underline{w} = -\underline{w}$.

Since the disturbance states z_1 and z_2 cannot, in general, be measured, in order to implement the control $\underline{u}_c$ the state reconstructor given by Equation (3) must be used to provide $\hat{z}_1$ and $\hat{z}_2$. The DAC control for this configuration will then be given by

$$\underline{u}_c = -\underline{w} = -h_1\hat{z}_1 - h_2\hat{z}_2 \ . \qquad (13)$$

V. STATE RECONSTRUCTOR DESIGN

In order to implement the state reconstructor, it is first necessary

to design the gain matrices $\underline{K}_1$ and $\underline{K}_2$. This is done by using Equation (5) with

$$\underline{K}_1 = \begin{bmatrix} k_{11} \\ k_{21} \\ k_{31} \\ k_{41} \end{bmatrix} \qquad \underline{K}_2 = \begin{bmatrix} k_{12} \\ k_{22} \end{bmatrix} . \tag{14}$$

Substituting the appropriate values into the first term on the right-hand side of Equation (5) and performing the indicated matrix multiplications and additions will result in the relation

$$\begin{pmatrix} \dot{\underline{\varepsilon}}_x \\ \dot{\underline{\varepsilon}}_z \end{pmatrix} = \left[\begin{array}{cccc|cc} (k_{11} - b_5) & 1 & 0 & 0 & h_1K(b_1 - b_5 + k_{11}) & h_2K(b_1 - b_5 + k_{11}) \\ (k_{21} - b_6) & 0 & 1 & 0 & h_1K(b_2 - b_6 + k_{21}) & h_2K(b_2 - b_6 + k_{21}) \\ (k_{31} - b_7) & 0 & 0 & 1 & h_1K(b_3 - b_7 + k_{31}) & h_2K(b_3 - b_7 + k_{31}) \\ (k_{41} - b_8) & 0 & 0 & 0 & h_1K(b_4 - b_8 + k_{41}) & h_2K(b_4 - b_8 + k_{41}) \\ \hline k_{12} & 0 & 0 & 0 & (d_1 + Kh_1k_{12}) & (d_3 + Kh_2k_{12}) \\ k_{22} & 0 & 0 & 0 & (d_2 + Kh_1k_{22}) & (d_4 + Kh_2k_{22}) \end{array}\right] \underline{\varepsilon} + \begin{bmatrix} \underline{o} \\ \underline{\sigma} \end{bmatrix} . \tag{15}$$

For computation simplification, let this be

$$\dot{\underline{\varepsilon}} = \tilde{\underline{A}}\,\underline{\varepsilon} + \begin{bmatrix} \underline{o} \\ \underline{\sigma} \end{bmatrix} \tag{16}$$

and represent $\tilde{\underline{A}}$ as

$$\tilde{\underline{A}} = \begin{bmatrix} e_0 & 1 & 0 & 0 & e_6 & e_{12} \\ e_1 & 0 & 1 & 0 & e_7 & e_{13} \\ e_2 & 0 & 0 & 1 & e_8 & e_{14} \\ e_3 & 0 & 0 & 0 & e_9 & e_{15} \\ e_4 & 0 & 0 & 0 & e_{10} & e_{16} \\ e_5 & 0 & 0 & 0 & e_{11} & e_{17} \end{bmatrix} . \tag{17}$$

Now, $\tilde{\underline{A}}$ represents the characteristic matrix of the $\dot{\underline{\varepsilon}}$ dynamics. As stated earlier, it is desired that $\underline{\Sigma}(t) \to o$ "rapidly" for good reconstructor performance. This means that the roots of the characteristic equation,

$$\det\left[\tilde{\underline{A}} - \lambda\underline{I}\right] = 0,$$

should be "large" negative numbers. The next step, therefore, (and generally the most tedious), is to calculate

$$\det\left[\tilde{\underline{A}} - \lambda\underline{I}\right].$$

Remember that $\tilde{\underline{A}}$ has unknown gain components included and is not just an array of known numbers. Therefore, we have

$$\det\left[\tilde{\underline{A}} - \lambda \underline{I}\right] = \begin{vmatrix} (e_o - \lambda) & 1 & 0 & 0 & e_6 & e_{12} \\ e_1 & -\lambda & 1 & 0 & e_7 & e_{13} \\ e_2 & 0 & -\lambda & 1 & e_8 & e_{14} \\ e_3 & 0 & 0 & -\lambda & e_9 & e_{15} \\ e_4 & 0 & 0 & 0 & e_{10}-\lambda & e_{16} \\ e_5 & 0 & 0 & 0 & e_{11} & e_{17}-\lambda \end{vmatrix} = 0 \; .$$

Evaluating this gives

$$\begin{aligned} |A - \lambda \underline{I}| = \; & \lambda^6 - (e_o + e_{10} + e_{17}) \lambda^5 + (e_0 e_{10} + e_0 e_{17} - e_{11} e_{16} + e_{10} e_{17} \\ & - e_1 - e_4 e_6 - e_5 e_{12}) \lambda^4 + (e_0 e_{11} e_{16} - e_0 e_{10} e_{17} + e_1 e_{10} \\ & + e_1 e_{17} - e_2 + e_4 e_6 e_{17} - e_4 e_{11} e_{12} - e_4 e_7 - e_5 e_6 e_{16} + e_5 e_{10} e_{12} \\ & - e_5 e_{13}) \lambda^3 + (e_1 e_{11} e_{16} - e_1 e_{10} e_{17} + e_2 e_{10} + e_2 e_{17} - e_3 \\ & + e_4 e_7 e_{17} - e_4 e_{11} e_{13} - e_4 e_8 - e_5 e_7 e_{16} + e_5 e_{10} e_{13} - e_5 e_{14}) \lambda^2 \\ & + (e_2 e_{11} e_{16} - e_2 e_{10} e_{17} + e_3 e_{10} + e_3 e_{17} + e_4 e_8 e_{17} - e_4 e_{11} e_{14} \\ & - e_4 e_9 - e_5 e_8 e_{16} + e_5 e_{10} e_{14} - e_5 e_{15}) \lambda + (- e_3 e_{10} e_{17} \\ & + e_3 e_{11} e_{16} + e_4 e_9 e_{17} - e_4 e_{11} e_{15} - e_5 e_9 e_{16} + e_5 e_{10} e_{15}) = 0 \; . \quad (18) \end{aligned}$$

If the desired roots of Equation (18) are λ_1, λ_2, λ_3, λ_4, λ_5, λ_6, then the desired characteristic equation is

$$(\lambda - \lambda_1)(\lambda - \lambda_2)(\lambda - \lambda_3)(\lambda - \lambda_4)(\lambda - \lambda_5)(\lambda - \lambda_6) = 0 \; . \quad (19)$$

Expanding Equation (19) and equating coefficients of like powers of λ between Equations (18) and (19) and substituting the proper symbols which the e_i represent results in the following:

$$\text{(a)} \quad k_{11} + Kh_1 k_{12} + Kh_2 k_{22} + (d_1 - b_5 + d_4) = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 = A_1 \quad ;$$

(b) $(d_1 + d_4)\, k_{11} + (-\, Kd_2h_2 + Kd_4h_1 - Kh_1b_1)\, k_{12} + (-Kd_3h_1 + Kd_1h_2$

$\quad - Kb_1h_2)\, k_{22} - k_{21} + (-\, b_5d_1 - b_5d_4 - d_2d_3 - d_1d_4 + b_6)$

$$= \sum_{j\,=\,1}^{5} \quad \sum_{j\,=\,i+1}^{6} \lambda_i\lambda_j = A_2 \quad ;$$

(c) $(d_3d_2 - d_1d_4)\, k_{11} + (Kh_1b_1d_4 - Kh_2b_1d_2 - Kh_1b_2)\, k_{12} + (-\, Kh_1b_1d_3$

$\quad +Kh_2b_1d_1 - Kh_2b_2)\, k_{22} + (d_1 + d_4)\, k_{21} - k_{31} + (-\, b_5d_3d_2$

$$+\, b_5d_1d_4 - b_6d_1 - b_6d_4 + b_7) = -\left[\begin{array}{l}\displaystyle\sum_{i\,=\,1}^{4} \quad \sum_{j\,=\,i+1}^{5} \quad \sum_{l\,=\,j+1}^{6} \\ \lambda_i\lambda_j\lambda_l = -A_3 \quad ;\end{array}\right]$$

(d) $(Kb_2h_1d_4 - Kb_2h_2d_2 - Kb_3h_1)\, k_{12} + (\, -\, Kb_2h_1d_3 + Kb_2h_2d_1 - Kb_3h_2)\, k_{22}$

$\quad + (d_3d_2 - d_1d_4)\, k_{21} + (d_1 + d_4)\, k_{31} - k_{41} + (-\, b_6d_3d_2 + b_6d_4d_1$

$$-\, b_7d_1 - b_7d_4 + b_8) = \left[\begin{array}{l}\displaystyle\sum_{i\,=\,1}^{3} \quad \sum_{j\,=\,i+1}^{4} \quad \sum_{l\,=\,j+1}^{5} \quad \sum_{n\,=\,l+1}^{6} \\ \lambda_i\lambda_j\lambda_l\lambda_n = A_4 \quad ;\end{array}\right]$$

(e) $(d_3d_2 - d_1d_4)\, k_{31} + (-\, d_3d_2b_7 + d_1d_4b_7 - d_1b_8 - d_4b_8) + (-\, Kh_1b_3d_3$

$\quad + Kh_2b_3d_1 + Kh_2b_4)\, k_{22} + (Kh_1b_3d_4 - Kh_2b_3d_2 - Kh_1b_4)\, k_{12} + (d_1 + d_4)\, k_{41}$

$\quad = -\left[\lambda_1\lambda_2\lambda_3\lambda_4\,(\lambda_5 + \lambda_6) + \lambda_1\lambda_2\lambda_5\lambda_6\,(\lambda_3 + \lambda_4) + \lambda_3\lambda_4\lambda_5\lambda_6\,(\lambda_1 + \lambda_2)\right]$

$\quad = -A_5 \quad ;$

(f) $(\, -\, d_1d_4 + d_3d_2)\, k_{41} + (b_8d_1d_4 - b_8d_2d_3) + (Kh_1b_4d_4 - Kh_2b_4d_2)\, k_{12}$

$\quad + (-\, Kd_3b_4h_1 + Kd_1h_2b_4)\, k_{22} = \lambda_1\lambda_2\lambda_3\lambda_4\lambda_5\lambda_6 = A_6 \; .$

For ease of manipulation, let us re-express (a) - (f) as

$$\begin{array}{lllll}
\text{(a)} & k_{11} & + m_0k_{12} + m_1k_{22} + m_2 & = & A_1 \\
\text{(b)} & m_3k_{11} - k_{21} & + m_4k_{12} + m_5k_{22} + m_6 & = & A_2 \\
\text{(c)} & m_7k_{11} + m_8k_{21} - k_{31} & + m_9k_{12} + m_{10}k_{22} + m_{11} & = & -\,A_3 \\
\text{(d)} & \quad m_{12}k_{21} + m_{13}k_{31} - k_{41} & + m_{14}k_{12} + m_{15}k_{22} + m_{16} & = & A_4 \\
\text{(e)} & \quad\quad m_{17}k_{31} + m_{18}k_{41} & + m_{19}k_{12} + m_{20}k_{22} + m_{21} & = & -\,A_5 \\
\text{(f)} & \quad\quad\quad m_{22}k_{41} & + m_{23}k_{12} + m_{24}k_{22} + m_{25} & = & A_6
\end{array}$$

or, in matrix form,

$$\begin{bmatrix} 1 & 0 & 0 & 0 & m_0 & m_1 \\ m_3 & -1 & 0 & 0 & m_4 & m_5 \\ m_7 & m_8 & -1 & 0 & m_9 & m_{10} \\ 0 & m_{12} & m_{13} & -1 & m_{14} & m_{15} \\ 0 & 0 & m_{17} & m_{18} & m_{19} & m_{20} \\ 0 & 0 & 0 & m_{22} & m_{23} & m_{24} \end{bmatrix} \begin{bmatrix} k_{11} \\ k_{21} \\ k_{31} \\ k_{41} \\ k_{12} \\ k_{22} \end{bmatrix} = \begin{bmatrix} A_1 - m_2 \\ A_2 - m_6 \\ -A_3 - m_{11} \\ A_4 - m_{16} \\ -A_5 - m_{21} \\ A_6 - m_{25} \end{bmatrix} \tag{20}$$

Therefore, we have $\underline{X}_m \begin{bmatrix} \underline{K}_1 \\ \underline{K}_2 \end{bmatrix} = \underline{R}$, where $\underline{K}_1 = \begin{bmatrix} k_{11} \\ k_{21} \\ k_{31} \\ k_{41} \end{bmatrix}$, $\underline{K}_2 = \begin{bmatrix} k_{12} \\ k_{22} \end{bmatrix}$. (21)

Solving for $\begin{bmatrix} \underline{K}_1 \\ \underline{K}_2 \end{bmatrix}$ gives $\begin{bmatrix} \underline{K}_1 \\ \underline{K}_2 \end{bmatrix} = \underline{X}_m^{-1}\underline{R}$ where $\underline{X}_m^{-1}$ denotes the inverse of the matrix $\underline{X}_m$. Since $\underline{X}_m$ is composed of known numbers when the desired values of λ_1 to λ_6 are substituted in, this matrix can be inverted via use of a matrix inversion subroutine.

Therefore, the components of the gain matrices $\underline{K}_1$ and $\underline{K}_2$ are determined as functions of the plant and disturbance parameters and the values of λ_1 through λ_6 chosen by the designer. It will usually be necessary to go through several iterations on values for the λ's before the desired observer performance is obtained.

Having these gains, it is now possible to construct the state observer, Equation (3), as

$$\begin{pmatrix} \dot{\hat{x}}_1 \\ \dot{\hat{x}}_2 \\ \dot{\hat{x}}_3 \\ \dot{\hat{x}}_4 \\ \dot{\hat{z}}_1 \\ \dot{\hat{z}}_2 \end{pmatrix} = \begin{bmatrix} (k_{11} - b_5) & 1 & 0 & 0 & h_1K(b_1 - b_5 + k_{11}) & h_2K(b_1 - b_5 + k_{11}) \\ (k_{21} - b_6) & 0 & 1 & 0 & h_1K(b_2 - b_6 + k_{21}) & h_2K(b_2 - b_6 + k_{21}) \\ (k_{31} - b_7) & 0 & 0 & 1 & h_1K(b_3 - b_7 + k_{31}) & h_2K(b_3 - b_7 + k_{31}) \\ (k_{41} - b_8) & 0 & 0 & 0 & h_1K(b_4 - b_8 + k_{41}) & h_2K(b_4 - b_8 + k_{41}) \\ k_{12} & 0 & 0 & 0 & (d_1 + Kh_1k_{12}) & (d_3 + Kh_2k_{12}) \\ k_{22} & 0 & 0 & 0 & (d_2 + Kh_1k_{22}) & (d_4 + Kh_2k_{22}) \end{bmatrix} \begin{pmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_3 \\ \hat{x}_4 \\ \hat{z}_1 \\ \hat{z}_2 \end{pmatrix}$$

$$- \begin{bmatrix} k_{11} \\ k_{21} \\ k_{31} \\ k_{41} \\ k_{12} \\ k_{22} \end{bmatrix} \underline{y}(t) + \begin{bmatrix} K(b_1 - b_5 + k_{11}) \\ K(b_2 - b_6 + k_{21}) \\ K(b_3 - b_7 + k_{31}) \\ K(b_4 - b_8 + k_{41}) \\ Kk_{12} \\ Kk_{22} \end{bmatrix} \underline{u}(t) \qquad (21)$$

and thus obtain the disturbance state estimates, $\hat{z}_1$ and $\hat{z}_2$, required for the DAC control $\underline{u}_c$.

Figure 3 presents the overall block diagram for the composite plant-state reconstructor model. The symbols r_i, p_i, v_i relate to matrix elements from Equation 21 as shown in Table 1.

VI. DIGITAL SIMULATION

This simulation has been assembled, for use on a CDC 6600 digital computer, in order to permit the design of DAC's for systems of the type shown in Figure 1 without the necessity of having to go through the tedious task of expanding determinants by hand. This simulation can be used in a design process to determine the necessary gains for a given system and then simulate that system's operation for various disturbance conditions. Or, the simulation could be modified and used as a subroutine in a larger program to provide a necessary disturbance control value when called.

As a design tool used by itself, the simulation will perform the following tasks: (1) calculate the elements of the gain matrices $\underline{K}_1$ and $\underline{K}_2$ utilizing the plant and disturbance input parameters and the λ's input by the designer; (2) implement the state reconstructor; (3) calculate the DAC control vector;

$$\underline{u}_c = - h_1 z_1 - h_2 \hat{z}_2,$$

and (4) close the DAC control loop through the plant to provide output data showing the overall performance obtained.

As a subroutine, the necessary plant output and other data can be transferred in through a COMMON block; the gains can be updated, if required by changing plant parameters; the value for $\underline{u}_c$ can be determined; and then required data can be transferred out through a COMMON block.

An overall program dictionary is presented in Table 2. Table 3 lists the NAMELIST inputs for the program, and Table 4 lists the outputs. A System Library Line Printer Plot Routine is used to plot the output, Y, and the disturbance state estimates $\hat{z}_1$, $\hat{z}_2$.

A listing of the simulation is given in Appendix A and the results of several disturbance cases for a given plant are shown in Appendix B.

The line-plot and matrix inversion subroutines used in this simulation were taken from Reference 6.

TABLE 1. EQUIVALENCES FOR FIGURE 3 SYMBOLS

$r_1 = k_{11} - b_5$	$p_7 = Kh_2(b_1 - b_5 + k_{11})$
$r_2 = k_{21} - b_6$	$p_8 = Kh_2(b_2 - b_6 + k_{21})$
$r_3 = k_{31} - b_7$	$p_9 = Kh_2(b_3 - b_7 + k_{31})$
$r_4 = k_{41} - b_8$	$p_{10} = Kh_2(b_4 - b_8 + k_{41}$
$p_1 = Kh_1(b_1 - b_5 + k_{11})$	$p_{11} = d_3 + Kh_2k_{12}$
$p_2 = Kh_1(b_2 - b_6 + k_{21})$	$p_{12} = d_4 + Kh_2k_{22}$
$p_3 = Kh_1(b_3 - b_7 + k_{31})$	$v_1 = K(b_1 - b_5 + k_{11})$
$p_4 = Kh_1(b_4 - b_8 + k_{41})$	$v_2 = K(b_2 - b_6 + k_{21})$
$p_5 = d_1 + Kh_1k_{12}$	$v_3 = K(b_3 - b_7 + k_{31})$
$p_6 = d_2 + Kh_1k_{22}$	$v_4 = K(b_4 - b_8 + k_{41})$

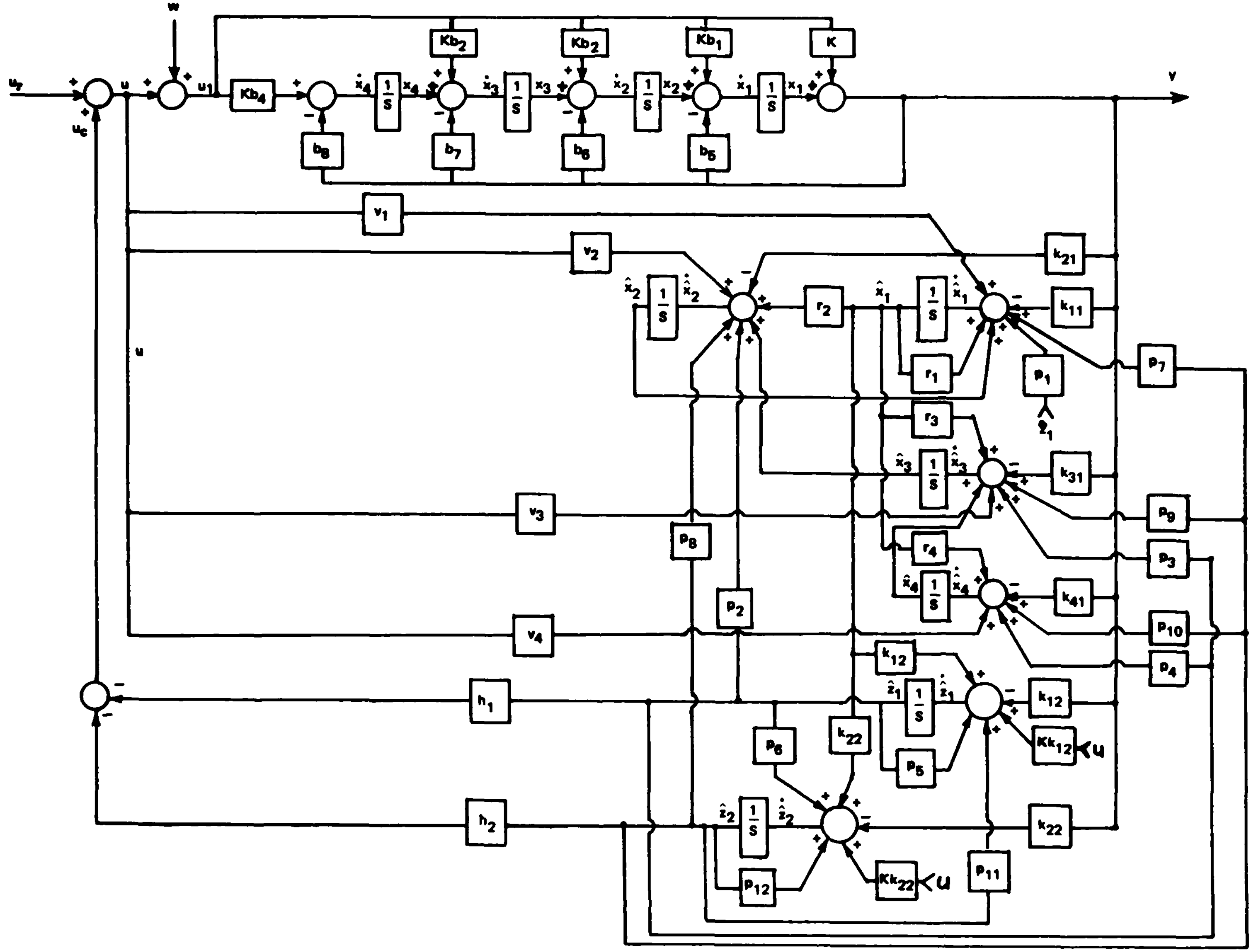

Figure 3. Composite plant - DAC block diagram.

TABLE 2. PROGRAM DICTIONARY

FORTRAN NAME	SYMBOL	DEFINITION
A	A_i	Coefficients of the desired characteristic equation associated with $[\tilde{\underline{A}} - \lambda \underline{I}]$ calculated using input eigenvalues.
AMO-AM25	m_i	Coefficients of the characteristic equation associated with $[\tilde{\underline{A}} - \lambda \underline{I}]$ calculated using actual plant and disturbance input parameters, factored according to components of the $\underline{K}_1$ and $\underline{K}_2$ matrices.
B	b_j	Coefficients in the plant transfer function.
CO, C1	C_o, C_1	Coefficients used in defining $\underline{w}(t)$.
C	K	Plant transfer function gain value.
CU1		Defined as $K \cdot U_1$.
CK	$\underline{K}_1$, $\underline{K}_2$	Array containing computed values for the gain matrices. CK(1) - CK(4) correspond to $\underline{K}_1$, CK(5) and CK(6) correspond to $\underline{K}_2$.
D	d_i	Array consisting of the elements of the $\underline{D}$ matrix associated with the disturbance state model.
DT	Δt	Integration step size.
H	h_i	Array consisting of elements of the $\underline{H}$ matrix associated with the disturbance state model.
KUTTA		Integration loop counter.
KU		Integration loop counter.
LM	λ_i	Eigenvalues of $\lvert \tilde{\underline{A}} - \lambda \underline{I} \rvert = 0$ chosen by designer to settle out state reconstructor response.
NX		Number of derivatives to be integrated.
PGO	u_r	Plant Input Command

TABLE 2. (CONCLUDED)

FORTRAN NAME	SYMBOL	DEFINITION
R	$\underline{R}$	Matrix used in solving for $\underline{K}_1$ and $\underline{K}_2$.
STPSZ		Used to define integration step size Δt = 1./STPSZ.
T		Intermediate terms, comprised of various combinations of the λ's, defined for use in later equations.
TIME	t	Total elapsed time (sec).
TSTOP	t_{stop}	Run end time (sec).
U1	u_1	Summation of u with disturbance magnitude, w.
U	u	Summation of plant input command, $\underline{u}_r$, DAC control term, $\underline{u}_c$, and plant output feedback, y.
UDA	$\underline{u}_c$	DAC control vector.
W	$\underline{w}(t)$	Disturbance vector.
X1 - X4	$x_1 - x_4$	Plant states.
XD1 - XD4	$\dot{x}_1 - \dot{x}_4$	Plant state derivatives.
XDH1 - XDH4	$\dot{\hat{x}}_1 - \dot{\hat{x}}_4$	State reconstructor state derivatives corresponding to $\dot{x}_1 - \dot{x}_4$.
XH1 - XH4	$\hat{x}_1 - \hat{x}_4$	State reconstructor states corresponding to $x_1 - x_4$.
XM		Array of elements of $\underline{X}_m$ matrix.
Y	y	Plant output.
Z		Intermediate terms, composed of various combinations of the λ's, defined for use in simplifying later equations.
ZDH1, ZDH2	$\dot{\hat{z}}_1, \dot{\hat{z}}_2$	State reconstructor disturbance state derivatives.
ZH1, ZH2	$\hat{z}_1, \hat{z}_2$	State reconstructor disturbance state estimates.

TABLE 3. NAMELIST INPUT VARIABLES

FORTRAN NAME	SYMBOL	DEFINITION
B	b_i	Array consisting of the coefficients, $b_1 - b_8$, of the plant transfer function y/u_1.
C	K	Plant transfer function gain value.
CO, C1	c_o, c_1	Coefficients used in defining $\underline{w}(t)$.
D	d_i	Array consisting of the elements of the $\underline{D}$ matrix associated with the disturbance state model. The elements are entered according to the subscripts shown in Equation (12).
H	h_i	Array consisting of elements of the $\underline{H}$ matrix associated with the disturbance model. The elements are entered according to the subscripts shown in Equation (11).
LM	λ_i	Array consisting of designer's choice of roots for the characteristic equation of $\lvert\tilde{A} - \lambda I\rvert$. The array permits input of complex conjugate values for the roots in the form $a \pm jb$. For this reason, the input format which must be used is: (RE_1, IM_1), (RE_2, IM_2), (RE_3, IM_3), (RE_4, IM_4), (RE_5, IM_5), (RE_6, IM_6).
NPRT	-	Used to control output print interval.
NUMBR	-	Used to control data storage for plots.
NX	-	Number of derivatives to be integrated by the Runge-Kutta integration subroutine.
PGO	u_r	Plant input command.
STPSZ	-	Used to define integration step size as, DT = 1./STPSZ (sec).
TSTOP	t_{STOP}	Run end time (sec).

TABLE 4. DIGITAL SIMULATION OUTPUT VARIABLES

FORTRAN NAME	SYMBOL	DEFINITION
PGO	$\underline{u}_r$	Plant input command
TIME	t	Total elapsed time since beginning of run (sec)
UDA	$\underline{u}_c$	DAC control vector
W	w	Disturbance magnitude as determined from differential equation used to describe it.
X1 - X4	x_1 - x_4	Plant states
XD1 - XD4	$\dot{x}_1$ - $\dot{x}_4$	Plant state derivatives
XDH1 - XDH4	$\dot{\hat{x}}_1$ - $\dot{\hat{x}}_4$	State reconstructor state derivatives corresponding to XD1 - XD4.
XH1 - XH4	$\hat{x}_1$ - $\hat{x}_4$	State reconstructor state estimates corresponding to X1 - X4.
Y	y	Plant output.
ZDH1, ZDH2	$\dot{\hat{z}}_1$, $\dot{\hat{z}}_2$	State reconstructor disturbance state derivatives.
ZH1, ZH2	$\hat{z}_1$, $\hat{z}_2$	State reconstructor disturbance state estimates.

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APPENDIX A

DIGITAL SIMULATION LISTING

```
      PROGRAM MAIN ( INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT )
C
      COMMON/DEFDAT/       ALF,            B ( 8 ),        BET,
     .     C,              CO,
     .     C1,             D ( 4 ),        H ( 2 ),        LM ( 6 ),
     .     NPRT,           NUMBR,          RCC,            STPSZ,
     .     TSTOP
C
      COMMON/INTEG/        NX
C
      COMMON/OUTP/ AM0,       AM1,       AM2,       AM3,       AM4,
     .     AM5,       AM6,       AM7,       AM8,       AM9,       AM10,
     .     AM11,      AM12,      AM13,      AM14,      AM15,      AM16,
     .     AM17,      AM18,      AM19,      AM20,      AM21,      AM22,
     .     AM23,      AM24,      AM25
C
      COMMON/BLNK/         DT,             KUTT
C
      COMMON/RUNKIN/
     .     XD1,       XD2,       XD3,       XD4,
     .     XDH1,      XDH2,      XDH3,      XDH4,      ZDH1,      ZDH2
C
      COMMON/BLNKOUT/
     .     X1,        X2,        X3,        X4,
     .     XH1,       XH2,       XH3,       XH4,       ZH1,       ZH2
C
      COMPLEX              LM,             T,              Z
C
      DIMENSION            A ( 6 ),        AM ( 26 ),      CK ( 6 ),
     .     HEAD ( 8 ),     IHLD ( - ),     P ( 6 ),        T ( 6 ),
     .     WORK ( 12 ),    XM ( 6, 12 ),   XMT ( 6, 6 ),   XT ( 1000 ),
     .     YT ( 1000 ),    Z ( 15 ),       Z1T ( 1000 ),   Z2T ( 1000 )
C
      EQUIVALENCE  ( AM ( 1 ), AM0 )
C
C
      NAMELIST/INP/        ALF,       B,         BET,
     .     C,         CO,        C1,
     .     D,         H,         LM,        NPRT,      NUMBR,     NX,
     .     RCC,       STPSZ,     TSTOP
C
      READ(5,100) HEAD
      READ(5,INP)
C
      WRITE(6,INP)
C
      WRITE(6,150) HEAD
C
      DO 10 I = 1, 6
      DO 10 J = 1, 12
   10 XM(I,J) = 0.0
      Z(1)    = LM ( 1 ) + LM ( 2 )
      Z(2)    = LM ( 1 ) + LM ( 3 )
      Z(3)    = LM ( 1 ) + LM ( 4 )
      Z(4)    = LM ( 1 ) + LM ( 5 )
      Z(5)    = LM ( 1 ) + LM ( 6 )
      Z(6)    = LM ( 2 ) + LM ( 3 )
```


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```
      Z(7)     = LM ( 2 ) * LM ( 4 )
      Z(8)     = LM ( 2 ) * LM ( 5 )
      Z(9)     = LM ( 2 ) * LM ( 6 )
      Z(10)    = LM ( 3 ) * LM ( 4 )
      Z(11)    = LM ( 3 ) * LM ( 5 )
      Z(12)    = LM ( 3 ) * LM ( 6 )
      Z(13)    = LM ( 4 ) * LM ( 5 )
      Z(14)    = LM ( 4 ) * LM ( 6 )
      Z(15)    = LM ( 5 ) * LM ( 6 )
      T(1)     = LM ( 3 ) + LM ( 4 ) + LM ( 5 ) + LM ( 6 )
      T(2)     = LM ( 4 ) + LM ( 5 ) + LM ( 6 )
      T(3)     = LM ( 5 ) + LM ( 6 )
      T(4)     = LM ( 3 ) + LM ( 4 )
      T(5)     = LM ( 1 ) + LM ( 2 )
      WRITE(6,300) T
      A(1)     = T ( 5 ) + T ( 4 ) + T ( 3 )
      A(2)     = Z ( 1 ) + Z ( 2 ) + Z ( 3 ) + Z ( 4 ) +
     .   Z ( 5 ) + Z ( 6 ) + Z ( 7 ) + Z ( 8 ) +
     .   Z ( 9 ) + Z ( 10 ) + Z ( 11 ) + Z ( 12 ) +
     .   Z ( 13 ) + Z ( 14 ) + Z ( 15 )
      A(3)     = Z ( 1 ) * T ( 1 ) + Z ( 2 ) * T ( 2 ) +
     .   Z ( 3 ) * T ( 3 ) + Z ( 4 ) * LM ( 6 ) +
     .   Z ( 6 ) * T ( 2 ) + Z ( 7 ) * T ( 3 ) +
     .   Z ( 8 ) * LM ( 6 ) + Z ( 10 ) * T ( 3 ) +
     .   Z ( 11 ) * LM ( 6 ) + Z ( 13 ) * LM ( 6 )
      A(4)     = Z ( 1 ) * ( Z ( 10 ) + Z ( 11 ) + Z ( 12 ) +
     .   Z ( 13 ) + Z ( 14 ) + Z ( 15 ) ) +
     .   Z ( 2 ) * ( Z ( 13 ) + Z ( 14 ) + Z ( 15 ) ) +
     .   Z ( 3 ) * Z ( 15 ) + Z ( 6 ) * ( Z ( 13 ) + Z ( 14 ) +
     .   Z ( 15 ) ) + Z ( 7 ) * Z ( 15 ) + Z ( 10 ) * Z ( 15 )
      A(5)     = Z ( 1 ) * Z ( 10 ) * T ( 3 ) +
     .   Z ( 1 ) * Z ( 15 ) * T ( 4 ) +
     .   Z ( 10 ) * Z ( 15 ) * T ( 5 )
      A(6)     = Z ( 1 ) * Z ( 10 ) * Z ( 15 )
      WRITE(6,400) A
      AM0      = C * H ( 1 )
      AM1      = C * H ( 2 )
      AM2      = D ( 1 ) - B ( 5 ) + D ( 4 )
      AM3      = D ( 1 ) + D ( 4 )
      AM8      = AM13 = AM18 = AM3
      AM4      = C * ( - D ( 2 ) * H ( 2 ) + D ( 4 ) * H ( 1 ) -
     .   H ( 1 ) * B ( 1 ) )
      AM5      = - C * ( D ( 3 ) * H ( 1 ) - D ( 1 ) * H ( 2 ) +
     .   H ( 2 ) * B ( 1 ) )
      AM7      = D ( 3 ) * D ( 2 ) - D ( 1 ) * D ( 4 )
      AM12     = AM17 = AM22 = AM7
      AM6      = - B ( 5 ) * AM3 + B ( 6 ) - AM7
      AM25     = - B ( 8 ) * AM7
      AM21     = - B ( 8 ) * AM3 - B ( 7 ) * AM7
      AM16     = - B ( 6 ) * AM7 - B ( 7 ) * AM3 + B ( 8 )
      AM11     = - B ( 5 ) * AM7 - B ( 6 ) * AM3 + B ( 7 )
      AM9      = C * ( H ( 1 ) * B ( 1 ) * D ( 4 ) -
     .   H ( 2 ) * B ( 1 ) * D ( 2 ) - H ( 1 ) * B ( 2 ) )
      AM10     = - C * ( H ( 1 ) * B ( 1 ) * D ( 3 ) -
     .   H ( 2 ) * B ( 1 ) * D ( 1 ) + H ( 2 ) * B ( 2 ) )
      AM14     = C * ( B ( 2 ) * H ( 1 ) * D ( 4 ) -
     .   H ( 2 ) * H ( 2 ) * D ( 2 ) - B ( 3 ) * H ( 1 ) )
```

```
      AM15     = -C * ( B ( 3 ) * F ( 1 ) * D ( 3 ) -
     .   B ( 2 ) * F ( 2 ) * D ( 1 ) + B ( 3 ) * F ( 2 ) )
      AM19     = C * ( F ( 1 ) * B ( 3 ) * D ( 4 ) -
     .   F ( 2 ) * B ( 3 ) * D ( 2 ) - F ( 1 ) * B ( 4 ) )
      AM20     = - C * ( F ( 1 ) * B ( 3 ) * D ( 3 ) -
     .   F ( 2 ) * B ( 3 ) * D ( 1 ) + F ( 2 ) * B ( 4 ) )
      AM23     = C * ( F ( 1 ) * B ( 4 ) * D ( 4 ) -
     .   F ( 2 ) * B ( 4 ) * D ( 2 ) )
      AM24     = C * ( - D ( 3 ) * B ( 4 ) * F ( 1 ) +
     .   D ( 1 ) * F ( 2 ) * B ( 4 ) )
      DO 30 I = 1, 25, 5
   30 WRITE(6,600) I, AM(I), I+1, AM(I+1), I+2, AM(I+2),I+3, AM(I+3)
     .   I+4, AM(I+4)
      WRITE(6,700) AM25
      R(1)     = A ( 1 ) - AM2
      R(2)     = A ( 2 ) - AM6
      R(3)     = - A ( 3 ) - AM11
      R(4)     = A ( 4 ) - AM16
      R(5)     = - A ( 5 ) - AM21
      R(6)     = A ( 6 ) - AM26
      WRITE(6,500) R
C--------------------COLUMN NO. 1  ---  ELEMENTS 1 THRU 6
      XM(1,1) = 1.0
      XM(2,1) = AM3
      XM(3,1) = AM7
      XM(4,1) = XM(5,1) = XM(6,1) = 0.0
C--------------------COLUMN NO. 2  ---  ELEMENTS 7 THRU 12
      XM(1,2) = 0.0
      XM(2,2) = -1.0
      XM(3,2) = AM8
      XM(4,2) = AM12
      XM(5,2) = XM(6,2) = 0.0
C--------------------COLUMN NO. 3  ---  ELEMENTS 13 THRU 18
      XM(1,3) = XM(2,3) = 0.0
      XM(3,3) = -1.0
      XM(4,3) = AM13
      XM(5,3) = AM17
      XM(6,3) = 0.0
C--------------------COLUMN NO. 4  ---  ELEMENTS 19 THRU 24
      XM(1,4) = XM(2,4) = XM(3,4) = 0.0
      XM(4,4) = -1.0
      XM(5,4) = AM18
      XM(6,4) = AM22
C--------------------COLUMN NO. 5  ---  ELEMENTS 25 THRU 30
      XM(1,5) = AM0
      XM(2,5) = AM4
      XM(3,5) = AM9
      XM(4,5) = AM14
      XM(5,5) = AM19
      XM(6,5) = AM23
C--------------------COLUMN NO. 6  ---  ELEMENTS 31 THRU 36
      XM(1,6) = AM1
      XM(2,6) = AM5
      XM(3,6) = AM10
      XM(4,6) = AM15
      XM(5,6) = AM20
      XM(6,6) = AM24
```

```
      DO 20 I = 1, 6
   20 WRITE(6,200) I, XM(I,1), I, XM(I,2), I, XM(I,3),
     .   I, XM(I,4), I, XM(I,5), I, XM(I,6)
C--------------------CALCULATE INVERSE OF MATRIX * YM *
      CALL SESOMI ( XM, 6, 6, 1, 6, DET, RA, E, WORK, IHLD, 1, 1, 1 )
      IF ( DET .EQ. 0.0 .OR. E .EQ. 1.0 ) GO TO 2200
      IF ( E .EQ. 2.0 ) WRITE(6, 5200)
      DO 40 I = 1, 6
   40 WRITE(6,200) I, XM(I,1), I, XM(I,2), I, XM(I,3),
     .   I, XM(I,4), I, XM(I,5), I, XM(I,6)
      WRITE(6,800) DET, RA, E
      DO 50 I = 1, 6
      DO 50 J = 1, 6
   50 XMI(I,J)= XM ( I, J )
      CALL MMPY ( XMI, B, CK, 6, 6, 1 )
      WRITE(6,900) CK
      XD1       = XD2 = XD3 = XD4 = 0.0
      X1        = X2 = X3 = X4 = 0.0
      XDH1      = XDH2 = XDH3 = XDH4 = ZDH1 = ZDH2 = 0.0
      XH1       = XH2 = XH3 = XH4 = ZH1 = ZH2 = 0.0
      DT        = 1.0 / STPSZ
      J         = 0
      TIME      = 0.0
      IP        = NPRT - 1
      ISTR      = STPSZ / NUMBR
      IPLT      = ISTR - 1
      NPTS      = 0
      YMAX      = -1000000.0
      YMIN      = 1000000.0
      YMAX1     = YMAX2 = -1000000.0
      YMIN1     = YMIN2 = 1000000.0
 1010 CONTINUE
      IF ( TIME .GE. TSTOP ) GO TO 1000
      J         = J + 1
      DO 2000 KU = 1, 4
      RUTTA     = KU
      C         = C0 + C1 * EXP( ALP * TIME )
      UDA       = H ( 1 ) * ZH1 + H ( 2 ) * ZH2
      U         = RCC - UDA - Y
      U1        = U + W
      CU1       = C * U1
      XD4       = CU1 * B ( 4 ) - B ( 8 ) * Y
      XD3       = X4 + CU1 * B ( 3 ) - B ( 7 ) * Y
      XD2       = X3 + CU1 * B ( 2 ) - B ( 6 ) * Y
      XD1       = X2 + CU1 * B ( 1 ) - B ( 5 ) * Y
      Y         = X1 + CU1
      XDH1      = ( CK ( 1 ) - B ( 5 ) ) * XH1 + XH2 +
     .   C * ( B ( 1 ) - B ( 5 ) + CK ( 1 ) ) *
     .   ( H ( 1 ) * ZH1 + H ( 2 ) * ZH2 + U ) - CK ( 1 ) * Y
      XDH2      = ( CK ( 2 ) - B ( 6 ) ) * XH1 + XH3 +
     .   C * ( B ( 2 ) - B ( 6 ) + CK ( 2 ) ) *
     .   ( H ( 1 ) * ZH1 + H ( 2 ) * ZH2 + U ) - CK ( 2 ) * Y
      XDH3      = ( CK ( 3 ) - B ( 7 ) ) * XH1 + XH4 +
     .   C * ( B ( 3 ) - B ( 7 ) + CK ( 3 ) ) *
     .   ( H ( 1 ) * ZH1 + H ( 2 ) * ZH2 + U ) - CK ( 3 ) * Y
      XDH4      = ( CK ( 4 ) - B ( 8 ) ) * XH1 +
     .   C * ( B ( 4 ) - B ( 8 ) + CK ( 4 ) ) *
```

```
     .   ( H ( 1 ) * ZH1 + H ( 2 ) * ZH2 + U ) - CK ( 4 ) * Y
      ZDH1     = CK ( 5 ) * XH1 + ( D ( 1 ) + C * H ( 1 ) * CK ( 5 ) ) *
     .   ZH1 + ( D ( 3 ) + C * H ( 2 ) * CK ( 5 ) ) *
     .   ZH2 - CK ( 5 ) * Y + C * CK ( 5 ) * U
      ZDH2     = CK ( 6 ) * XH1 + ( D ( 2 ) + C * H ( 1 ) * CK ( 6 ) ) *
     .   ZH1 + ( D ( 4 ) + C * H ( 2 ) * CK ( 6 ) ) *
     .   ZH2 - CK ( 6 ) * Y + C * CK ( 6 ) * U
      GO TO ( 5000, 6000, 3000, 4000 ), KUTTA
 5000 CONTINUE
      IPLT     = IPLT + 1
      IF ( IPLT .NE. ISTR ) GO TO 2020
      IPLT     = 0
      NPTS     = NPTS + 1
      XT(NPTS)= TIME
      YT(NPTS)= Y
      YMAX     = AMAX1 ( YMAX, Y )
      YMIN     = AMIN1 ( YMIN, Y )
      Z1T(NPTS)= ZH1
      Z2T(NPTS)= ZH2
      YMAX1    = AMAX1 ( YMAX1, ZH1 )
      YMIN1    = AMIN1 ( YMIN1, ZH1 )
      YMAX2    = AMAX1 ( YMAX2, ZH2 )
      YMIN2    = AMIN1 ( YMIN2, ZH2 )
 2020 CONTINUE
      IP       = IP + 1
      IF ( IP .NE. NPRT ) GO TO 2030
      IP       = 0
      WRITE(6,550) TIME,     XD1,      XD2,      XD3,      XD4,
     .   X1,       X2,       X3,       X4,       XDH1,     XDH2,
     .   XDH3,     XDH4,     ZDH1,     ZDH2,     XH1,      XH2,
     .   XH3,      XH4,      ZH1,      ZH2,      POC,      W,
     .   UDA,      Y
 2030 CONTINUE
 3000 TIME     = TIME + 0.5 * DT
 4000 CONTINUE
 6000 CALL RUNGK
 2000 CONTINUE
      GO TO 1010
 1000 CONTINUE
      NPTS     = NPTS + 1
      XT(NPTS)= TIME
      YT(NPTS)= Y
      YMAX     = AMAX1 ( YMAX, Y )
      YMIN     = AMIN1 ( YMIN, Y )
      Z1T(NPTS)= ZH1
      Z2T(NPTS)= ZH2
      YMAX1    = AMAX1 ( YMAX1, ZH1 )
      YMIN1    = AMIN1 ( YMIN1, ZH1 )
      YMAX2    = AMAX1 ( YMAX2, ZH2 )
      YMIN2    = AMIN1 ( YMIN2, ZH2 )
      WRITE(6,550) TIME,     XD1,      XD2,      XD3,      XD4,
     .   X1,       X2,       X3,       X4,       XDH1,     XDH2,
     .   XDH3,     XDH4,     ZDH1,     ZDH2,     XH1,      XH2,
     .   XH3,      XH4,      ZH1,      ZH2,      POC,      W,
     .   UDA,      Y
      CALL LINPLT ( XT, YT, DUMM, DUMM, NPTS, 1, YMIN, YMAX, 0., 0.,
     .   0., 0. )
```

```
      CALL LINPLT ( XT, Z1T, Z2T, DUMM, NPTS, 2, YMIN1, YMAX1,
     .   YMIN2, YMAX2, 0., 0. )
      GO TO 2100
 2200 CONTINUE
      WRITE(6,5100)
 2100 CONTINUE
      CALL EXIT
  100 FORMAT(8A10)
  150 FORMAT(1H1,1X,13(2H* ),8A10,13(2H* ),////)
  200 FORMAT(/,1X,3HXM(I1,4H,1)=,E12.6,1X,
     .   3HXM(I1,4H,2)=,E12.6,1X,3HXM(I1,4H,3)=,E12.6,1X,
     .   3HXM(I1,4H,4)=,E12.6,1X,3HXM(I1,4H,5)=,E12.6,1X,
     .   3HXM(I1,4H,6)=,E12.6)
  300 FORMAT(/,1X,*T(1)=*,2(E12.6,2X),1X,*T(2)=*,2(E12.6,2X),1X,
     .   *T(3)=*,2(E12.6,2X),/,1X,*T(4)=*,2(E12.6,2X),1X,
     .   *T(5)=*,2(E12.6,2X),/)
  400 FORMAT(/,1X,*A(1)=*E12.6,1X,*A(2)=*,E12.6,
     .   1X,*A(3)=*,E12.6,1X,*A(4)=*,E12.6,1X,
     .   *A(5)=*,E12.6,1X,*A(6)=*,E12.6,/)
  500 FORMAT(/,1X,*R(1)=*E12.6,1X,*R(2)=*,E12.6,
     .   1X,*R(3)=*,E12.6,1X,*R(4)=*,E12.6,1X,
     .   *R(5)=*,E12.6,1X,*R(6)=*,E12.6,/)
  550 FORMAT(/,4X,6HTIME =,E14.7,4X,6HXD1  =,E14.7,4X,
     .6HXD2  =,E14.7,4X,6HXD3  =,E14.7,4X,6HXD4  =,E14.7,/,
     .4X,6HX1   =,E14.7,4X,6HX2   =,E14.7,4X,6HX3   =,E14.7,4X,
     .6HX4   =,E14.7,4X,6HXDH1 =,E14.7,/,
     .4X,6HXDH2 =,E14.7,4X,6HXDH3 =,E14.7,4X,6HXDH4 =,E14.7,4X,
     .6HZDH1 =,E14.7,4X,6HZDH2 =,E14.7,/,4X,6HXH1  =,E14.7,4X,
     .6HXH2  =,E14.7,4X,6HXH3  =,E14.7,4X,6HXH4  =,E14.7,4X,
     .6HZH1  =,E14.7,/,4X,6HZH2  =,E14.7,4X,6HPEGC =,E14.7,4X,
     .6HW    =,E14.7,4X,6HUDA  =,E14.7,4X,6HY    =,E14.7,//)
  600 FORMAT(/,5(1X,3HAM(,I2,2H)=,E12.6))
  700 FORMAT(/,1X,*AM(26)=*,E12.6,/)
  800 FORMAT(////,5X,*DET=*,E14.7,3X,*RA=*,E14.7,3X,*E=*,E14.7)
  900 FORMAT(/,1X,*K(1)=*E12.6,1X,*K(2)=*,E12.6,
     .   1X,*K(3)=*,E12.6,1X,*K(4)=*,E12.6,1X,
     .   *K(5)=*,E12.6,1X,*K(6)=*,E12.6,/)
 5100 FORMAT(/////,28X,10(2H**),4X,34HMATRIX IS SINGULAR, RUN IS ABORTE
     ..,4X,10(2H**))
 5200 FORMAT(1X,68(2H**),//,35X,
     .56HSOLUTION IS ATTEMPTED BUT MATRIX MAY BE SINGULAR OR ILL
     .11HCONDITIONED,//,1X,68(2H**))
      END
```

```
        SYMBOLIC REFERENCE MAP (R=3)

ENTRY POINTS      DEF LINE      REFERENCES
 4114  MAIN            1

VARIABLES      SN  TYPE            RELOCATION
  6153  A          REAL       ARRAY              REFS       29        92       129       130       131       132       133
                                                  134     DEFINED      73        74        78        83        88        91
     0  ALP        REAL                DEFDAT    REFS        3        37       208
     0  AM         REAL       ARRAY    OUTP      REFS       25        34     5*126
     0  AM0        REAL                OUTP      REFS       11        34       159   DEFINED        97
     1  AM1        REAL                OUTP      REFS       11       166   DEFINED        94
    12  AM10       REAL                OUTP      REFS       11       168   DEFINED       111
    13  AM11       REAL                OUTP      REFS       11       131   DEFINED       108
    14  AM12       REAL                OUTP      REFS       11       145   DEFINED       103
    15  AM13       REAL                OUTP      REFS       11       150   DEFINED        97
    16  AM14       REAL                OUTP      REFS       11       162   DEFINED       113
    17  AM15       REAL                OUTP      REFS       11       169   DEFINED       115
    20  AM16       REAL                OUTP      REFS       11       132   DEFINED       107
    21  AM17       REAL                OUTP      REFS       11       151   DEFINED       103
    22  AM18       REAL                OUTP      REFS       11       156   DEFINED        97
    23  AM19       REAL                OUTP      REFS       11       163   DEFINED       117
     2  AM2        REAL                OUTP      REFS       11       129   DEFINED        95
    24  AM20       REAL                OUTP      REFS       11       170   DEFINED       115
    25  AM21       REAL                OUTP      REFS       11       133   DEFINED       106
    26  AM22       REAL                OUTP      REFS       11       157   DEFINED       103
    27  AM23       REAL                OUTP      REFS       11       164   DEFINED       121
    30  AM24       REAL                OUTP      REFS       11       171   DEFINED       123
    31  AM25       REAL                OUTP      REFS       11       128       134   DEFINED       105
     3  AM3        REAL                OUTP      REFS       11        97       104       106       107       108       138
                                               DEFINED      96
     4  AM4        REAL                OUTP      REFS       11       160   DEFINED        98
     5  AM5        REAL                OUTP      REFS       11       167   DEFINED       100
     6  AM6        REAL                OUTP      REFS       11       130   DEFINED       104
     7  AM7        REAL                OUTP      REFS       11       103       104       105       106       107       108
                                                  138   DEFINED       102
    10  AM8        REAL                OUTP      REFS       11       144   DEFINED        97
    11  AM9        REAL                OUTP      REFS       11       161   DEFINED       109
     1  B          REAL       ARRAY    DEFDAT    REFS        3        37        55        58       100     2*104       105
                                                2*106    3*107     3*108     3*109     3*111     3*113     3*115     3*117
                                                3*119    2*121     2*123     2*213     2*214     2*215     2*216     3*218
                                                3*221    3*224     3*227
    11  BET        REAL                DEFDAT    REFS        3        37
    12  C          REAL                DEFDAT    REFS        3        37        93        94        98       100       109
                                                  111      113       115       117       119       121       123       212
                                                  218      221       224       227     3*230     3*233
  6161  CK         REAL       ARRAY              REFS       29       186       187     3*218     3*221     3*224     3*227
                                                5*230    5*233
  6101  CL1        REAL                          REFS      213       214       215       216       217
                                               DEFINED     212
    13  C0         REAL                DEFDAT    REFS        3        37       208
    14  C1         REAL                DEFDAT    REFS        3        37       208
    15  D          REAL       ARRAY    DEFDAT    REFS        3        37      2*55      2*56      2*58     2*100     4*102
                                                2*109    2*111     2*113     2*115     2*117     2*119     2*121     2*123
                                                2*230    2*233
  6055  DET        REAL                          REFS      176       177       182
```

VARIABLES		SN	TYPE		RELOCATION								
0	CT		REAL		RUNK	REFS	17	262	DEFINED	192			
6102	DUMM		REAL			REFS	2*284	286					
6057	F		REAL			REFS	176	177	178	182			
21	H		REAL	ARRAY	DEFDAT	REFS	3	37	93	94	3*98	3*100	3*109
						3*111	3*113	3*115	3*117	3*119	2*121	2*123	2*209
						2*218	2*221	2*224	2*227	2*230	2*233		
6167	HEAD		REAL	ARRAY		REFS	29	47	DEFINED	42			
6053	I		INTEGER			REFS	51	10*126	12*173	12*180	2*185		
						DEFINED	49	125	172	179	183		
6177	IHLD		INTEGER	ARRAY		REFS	29	176					
6061	IP		INTEGER			REFS	253	254	DEFINED	195	253	255	
6063	IPLT		INTEGER			REFS	238	239	DEFINED	197	238	240	
6062	ISTR		INTEGER			REFS	197	239	DEFINED	196			
6054	J		INTEGER			REFS	51	2*185	205	DEFINED	50	184	193
						205							
6073	KU		INTEGER			REFS	207	DEFINED	206				
1	KUTTA		INTEGER		RUNK	REFS	17	236	DEFINED	207			
23	LM		COMPLEX	ARRAY	DEFDAT	REFS	3	27	37	2*52	2*53	2*54	2*55
						2*56	2*57	2*58	2*59	2*60	2*61	2*62	2*63
						2*64	2*65	2*66	4*67	3*68	2*69	2*70	2*71
						4*78							
37	NPRT		INTEGER		DEFDAT	REFS	3	37	195	254			
6064	NPTS		INTEGER			REFS	241	242	243	246	247	268	269
						270	273	274	284	286	DEFINED	198	241
						268							
40	NUMPR		INTEGER		DEFDAT	REFS	3	37	196				
0	NX		INTEGER		INTEG	REFS	9	37					
41	PSC		REAL		DEFDAT	REFS	3	37	210	256	275		
6205	R		REAL	ARRAY		REFS	29	135	186	DEFINED	129	130	131
						132	133	134					
6056	RA		REAL			REFS	176	182					
42	STPSZ		REAL		DEFDAT	REFS	3	37	192	196			
6103	T		COMPLEX	ARRAY		REFS	27	29	72	3*73	6*78	3*88	
						DEFINED	67	68	69	70	71		
6060	TIME		REAL			REFS	204	208	242	256	262	269	279
						DEFINED	194	262					
43	TSTOP		REAL		DEFDAT	REFS	3	37	204				
6076	U		REAL			REFS	211	218	221	224	227	230	233
						DEFINED	210						
6075	UCA		REAL			REFS	210	256	279	DEFINED	209		
6100	U1		REAL			REFS	212	DEFINED	211				
6074	W		REAL			REFS	211	256	279	DEFINED	208		
6213	WORK		REAL	ARRAY		REFS	29	176					
4	XCH1		REAL		RUNKIN	REFS	19	256	279	DEFINED	190	218	
5	XCH2		REAL		RUNKIN	REFS	19	256	279	DEFINED	190	221	
6	XCH3		REAL		RUNKIN	REFS	19	256	279	DEFINED	190	224	
7	XCH4		REAL		RUNKIN	REFS	15	256	279	DEFINED	190	227	
0	XC1		REAL		RUNKIN	REFS	19	256	279	DEFINED	188	216	
1	XC2		REAL		RUNKIN	REFS	19	256	279	DEFINED	188	215	
2	XC3		REAL		RUNKIN	REFS	19	256	279	DEFINED	188	214	
3	XC4		REAL		RUNKIN	REFS	19	256	279	DEFINED	188	213	
4	XH1		REAL		RUNKOUT	REFS	23	218	221	224	227	230	233
						256	279	DEFINED	191				
5	XH2		REAL		RUNKOUT	REFS	23	218	256	275	DEFINED	191	
6	XH3		REAL		RUNKOUT	REFS	23	221	256	275	DEFINED	191	
7	XH4		REAL		RUNKOUT	REFS	23	224	256	279	DEFINED	191	
6227	XM		REAL	ARRAY		REFS	29	6*173	176	6*180	185		

```
VARIABLES     SN   TYPE            RELOCATION
                                               DEFINED      51     137      138      135    3*140     142     143
                                                   144     145   2*146    2*148     149      150     151     152
                                                 3*154     155     156      157     159      160     161     162
                                                   163     164     166      167     168      165     170     171
  6337  XMI        REAL       ARRAY               REFS      29     186  DEFINED     185
  6403  XT         REAL       ARRAY               REFS      29     284      286  DEFINED      242     269
     0  X1         REAL              RUNKOUT      REFS      23     217      256     279  DEFINED     189
     1  X2         REAL              RUNKOUT      REFS      23     216      256     279  DEFINED     189
     2  X3         REAL              RUNKOUT      REFS      23     215      256     279  DEFINED     189
     3  X4         REAL              RUNKOUT      REFS      23     214      256     279  DEFINED     189
  6077  Y          REAL                           REFS     210     213      214     215      216     218     221
                                                   224     227     230      233     243      244     245     256
                                                   270     271     272      279  DEFINED      217
  6065  YMAX       REAL                           REFS     244     271      284  DEFINED      199     244     271
  6067  YMAX1      REAL                           REFS     248     275      286  DEFINED      201     248     275
  6070  YMAX2      REAL                           REFS     250     277      286  DEFINED      201     250     277
  6066  YMIN       REAL                           REFS     245     272      284  DEFINED      200     245     272
  6071  YMIN1      REAL                           REFS     249     276      286  DEFINED      202     249     276
  6072  YMIN2      REAL                           REFS     251     278      286  DEFINED      202     251     278
 10353  YT         REAL       ARRAY               REFS      29     284  DEFINED     243      270
  6115  Z          COMPLEX    ARRAY               REFS      27      29    15*74   10*78    21*83    6*88    3*91
                                               DEFINED      52      53       54      55       56      57      58
                                                    55      60      61       62      63       64      65      66
    10  ZCH1       REAL              RUNKIN       REFS      19     256      279  DEFINED      190     230
    11  ZCH2       REAL              RUNKIN       REFS      19     256      279  DEFINED      190     233
    10  ZH1        REAL              RUNKOUT      REFS      23     209      218     221      224     227     230
                                                   233     246     248      249     256      273     275     276
                                                   278 DEFINED     191
    11  ZH2        REAL              RUNKOUT      REFS      23     209      218     221      224     227     230
                                                   233     247     250      251     256      274     277     278
                                                   279 DEFINED     191
 12323  Z1T        REAL       ARRAY               REFS      29     286  DEFINED     246      273
 14273  Z2T        REAL       ARRAY               REFS      29     286  DEFINED     247      274

FILE NAMES         MODE
     0  INPUT
  2043  OUTPUT
     0  TAPE5      MIXED                READS       42      43
  2043  TAPE6      MIXED               WRITES       46      47      72       92     126      128     135     173
                                          178      180     182     187      256     279      290

EXTERNALS          TYPE    ARGS        REFERENCES
        EXIT                0             282
        EXP        REAL     1 LIBRARY     208
        LINPLT             12             284      286
        NMEY                6             186
        RUNCK               0             264
        SESCMI             13             176

INLINE FUNCTIONS   TYPE    ARGS      DEF LINE   REFERENCES
        AMAX1      REAL     0  INTRIN             244     248     250      271     275      277
        AMIN1      REAL     0  INTRIN             245     249     251      272     276      278

NAMELISTS          DEF LINE       REFERENCES
        INF           37          43         45
```

```
STATEMENT LABELS                 DEF LINE   REFERENCES
     0  10                            51        49        50
     0  20                           173       172
     0  30                           126       125
     0  40                           180       179
     0  50                           185       183       184
  5616  100      FMT                 293        42
  5620  150      FMT                 294        47
  5625  200      FMT                 295       173       180
  5644  300      FMT                 299        72
  5661  400      FMT                 302        62
  5675  500      FMT                 305       175
  5711  550      FMT                 309       256       279
  5763  600      FMT                 317       126
  5767  700      FMT                 318       128
  5773  800      FMT                 319       182
  6001  900      FMT                 320       187
  5204  1000                         267       204
  4774  1010                         203       266
     0  2000                         265       206
  5170  2020                         252       239
  5175  2030                         261       254
  5240  2100                         291       288
  5236  2200                         289       177
  5175  3000                         262       276
  5200  4000                         263       236
  5140  5000                         237       236
  6015  5100     FMT                 323       250
  6025  5200     FMT                 325       178
  5200  6000                         264       236

LOOPS   LABEL    INDEX      FROM-TO     LENGTH     PROPERTIES
  4126  10       * I         49 51        4S                 NOT INNER
  4127  10         J         50 51        2S        INSTACK
  4544  30       * I        125 126      22S                 EXT REFS
  4662  20       * I        172 173      16S                 EXT REFS
  4714  40       * I        175 180      16S                 EXT REFS
  4734  50       * I        183 185       5S                 NOT INNER
  4735  50         J        184 185       3S        INSTACK
  5000  2000     * KL       206 265     204S                 EXT REFS

COMMON BLOCKS  LENGTH     MEMBERS - BIAS NAME(LENGTH)
       DEFDAT      36                 0 ALP     (1)          1 B       (2)          5 BET     (1)
                                     10 C       (1)         11 C0      (1)         12 C1      (1)
                                     13 D       (4)         17 H       (2)         19 LP      (12)
                                     31 NFRT    (1)         32 NUMBR   (1)         33 PCO     (1)
                                     34 STPSZ   (1)         35 TSTOP   (1)
       INTEG        1                 0 NX      (1)
       OUTP        26                 0 AM0     (1)          1 AM1     (1)          2 AM2     (1)
                                      3 AM3     (1)          4 AM4     (1)          5 AM5     (1)
                                      6 AM6     (1)          7 AM7     (1)          8 AM8     (1)
                                      9 AM9     (1)         10 AM10    (1)         11 AM11    (1)
                                     12 AM12    (1)         13 AM13    (1)         14 AM14    (1)
                                     15 AM15    (1)         16 AM16    (1)         17 AM17    (1)
                                     18 AM18    (1)         19 AM19    (1)         20 AM20    (1)
                                     21 AM21    (1)         22 AM22    (1)         23 AM23    (1)
                                     24 AM24    (1)         25 AM25    (1)
```

```
COMMON BLOCKS    LENGTH      MEMBERS - BIAS NAME(LENGTH)
       RUNK           2                0 CT       (1)           1 KUTTA   (1)
       RUNKIN        10                0 XD1      (1)           1 XD2     (1)           2 XD3     (1)
                                       3 XD4      (1)           4 XDH1    (1)           5 XDH2    (1)
                                       6 XDH3     (1)           7 XDH4    (1)           8 ZDH1    (1)
                                       9 ZDH2     (1)
       RUNKOUT       10                0 X1       (1)           1 X2      (1)           2 X3      (1)
                                       3 X4       (1)           4 XH1     (1)           5 XH2     (1)
                                       6 XH3      (1)           7 XH4     (1)           8 ZH1     (1)
                                       9 ZH2      (1)

EQUIV CLASSES    LENGTH      MEMBERS - BIAS NAME(LENGTH)
-NO    AMO           26                0 AM       (26)

STATISTICS
  PROGRAM LENGTH                 12135B    5213
  BUFFER LENGTH                   4106B    2118
  CM LABELED COMMON LENGTH         125B      85
```

```
      BLOCK DATA A
C
      COMMON/DEFDAT/      ALP,            B ( 8 ),        BET,
     .    C,              C0,
     .    C1,             D ( 4 ),        H ( 2 ),        LM ( 6 ),
     .    NPRT,           NUMBR,          PGC,            STPSZ,
     .    TSTOP
C
      COMMON/INTEG/       NX
C
      COMPLEX             LM
      DATA                ALP             /1.0            /
      DATA                B
     .   /20.0,           -440.0,         -10800.0,       -54000.0,
     .    17.6816,        243.7748,       438.5048,       211.4116        /
      DATA                BET             /1.0            /
      DATA                C               /-0.03328       /
      DATA                C0              /0.0            /
      DATA                C1              /0.0            /
      DATA                D
     .   /0.0,            0.0,            1.0,            0.0             /
      DATA                H
     .   /1.0,            0.0             /
      DATA                LM
     .   /(-5.0,0.0),     (-6.0,0.0),     (-10.0,0.0),    (-10.0,0.0),
     .    (-12.0,0.0),    (-15.0,0.0)     /
      DATA                NPRT            /32             /
      DATA                NUMBR           /8              /
      DATA                NX              /10             /
      DATA                PGC             /1.0            /
      DATA                STPSZ           /32.0           /
      DATA                TSTOP           /10.0           /
      END
```

```
SYMBOLIC REFERENCE MAP (R=3)

VARIABLES      SN   TYPE             RELOCATION
     0  ALF         REAL                  DEFDAT       REFS         3     DEFINED     12
     1  B           REAL          ARRAY   DEFDAT       REFS         3     DEFINED     13
    11  BET         REAL                  DEFDAT       REFS         3     DEFINED     16
    12  C           REAL                  DEFDAT       REFS         3     DEFINED     17
    13  CO          REAL                  DEFDAT       REFS         3     DEFINED     18
    14  C1          REAL                  DEFDAT       REFS         3     DEFINED     19
    15  D           REAL          ARRAY   DEFDAT       REFS         3     DEFINED     20
    21  H           REAL          ARRAY   DEFDAT       REFS         3     DEFINED     22
    23  LM          COMPLEX       ARRAY   DEFDAT       REFS         3        11     DEFINED     24
    37  NPRT        INTEGER               DEFDAT       REFS         3     DEFINED     27
    40  NUMPR       INTEGER               DEFDAT       REFS         3     DEFINED     28
     0  NX          INTEGER               INTEG        REFS         5     DEFINED     29
    41  PCC         REAL                  DEFDAT       REFS         3     DEFINED     30
    42  STPSZ       REAL                  DEFDAT       REFS         3     DEFINED     31
    43  TSTOP       REAL                  DEFDAT       REFS         3     DEFINED     32

COMMON BLOCKS   LENGTH     MEMBERS - BIAS NAME(LENGTH)
   DEFDAT         36              0 ALF      (1)        1 B        (8)        5 BET     (1)
                                 10 C        (1)       11 CO       (1)       12 C1      (1)
                                 13 D        (4)       17 H        (2)       15 LM     (12)
                                 31 NPRT     (1)       32 NUMPR    (1)       33 PCC     (1)
                                 34 STPSZ    (1)       35 TSTOP    (1)
   INTEG           1              0 NX       (1)

STATISTICS
  PROGRAM LENGTH                   0B        0
  CM LABELED COMMON LENGTH        45B       37
```

```
      SUBROUTINE RUNGK
C
C
      COMMON/INTEG/      NX
C
C
C
      COMMON/RUNK/       DT,             KUTTA
C
C
C
C-------------------DERIVATIVES TO RUNGK
C                    DO NOT CHANGE THE ORDER OF THE MEMBERS
C
      COMMON/RUNKIN/
     .   XD1,       XD2,       XD3,       XD4,
     .   XDH1,      XDH2,      XDH3,      XDH4,      ZDH1,      ZDH2
C
C
C
C-------------------INTEGRALS FROM RUNGK
C                    DO NOT CHANGE THE ORDER OF THE MEMBERS
C
      COMMON/RUNKOUT/
     .   X1,        X2,        X3,        X4,
     .   XH1,       XH2,       XH3,       XH4,       ZH1,       ZH2
C
C
C
C
      DIMENSION          DX ( 10 ),     DXA ( 10 ),     XR ( 10 ),
     .   XA ( 10 )
C
C
C
      EQUIVALENCE  ( XR,        X1 ),  ( DX,      XD1  )
C
C
      GO TO (10,30,50,70),KUTTA
   10 DO 20 I=1,NX
      XA(I)    = XR ( I )
      DXA(I)=DT*DX(I)
   20 XR(I)    = XR ( I ) + 0.5 * DXA ( I )
      RETURN
   30 TDT=2.*DT
      HDT=.5*DT
      DO 40 I=1,NX
      DXA(I)=DXA(I)+TDT*DX(I)
   40 XR(I)    = XA ( I ) + HDT * DX ( I )
      RETURN
   50 DO 60 I=1,NX
      VDT=DT*DX(I)
      DXA(I)=DXA(I)+2.*VDT
   60 XR(I)    = XA ( I ) + VDT
      RETURN
   70 DO 80 I=1,NX
   80 XR(I)    = XA ( I ) + ( DXA ( I ) + DT * DX ( I ) ) / 6.0
```

```
      RETURN
      END
```

```
      SUBROUTINE RUNGK      74/74   OPT=0 TRACE                      FTN 4.6+439        03/04/80  08.49.44       PAGE     3

      SYMBOLIC REFERENCE MAP (R=3)

ENTRY POINTS      DEF LINE     REFERENCES
    2 RUNGK              1        44        50        55        58

VARIABLES      SN  TYPE             RELOCATION
    0 DT           REAL                  RUNK          REFS         8        42        45        46        52        57
    0 DX           REAL        ARRAY     RUNKIN        REFS        31        36        42        48        49        52        57
  117 DXA          REAL        ARRAY                   REFS        31        43        48        53        57
                                                     DEFINED       42        48        53
  115 HDT          REAL                                REFS        49   DEFINED        46
  113 I            INTEGER                             REFS      2*41      2*42      3*43      3*48      3*49        52      2*53
                                                         2*54    4*57   DEFINED        40        47        51        56
    1 KUTTA        INTEGER               RUNK          REFS         8        39
    0 NX           INTEGER               INTEG         REFS         4        40        47        51        56
  114 TDT          REAL                                REFS        48   DEFINED        45
  116 VDT          REAL                                REFS        53        54   DEFINED        52
  131 XA           REAL        ARRAY                   REFS        31        49        54        57   DEFINED        41
    4 XDH1         REAL                  RUNKIN        REFS        15
    5 XDH2         REAL                  RUNKIN        REFS        15
    6 XDH3         REAL                  RUNKIN        REFS        15
    7 XDH4         REAL                  RUNKIN        REFS        15
    0 XD1          REAL                  RUNKIN        REFS        15        36
    1 XD2          REAL                  RUNKIN        REFS        15
    2 XD3          REAL                  RUNKIN        REFS        15
    3 XD4          REAL                  RUNKIN        REFS        15
    4 XH1          REAL                  RUNKOUT       REFS        24
    5 XH2          REAL                  RUNKOUT       REFS        24
    6 XH3          REAL                  RUNKOUT       REFS        24
    7 XH4          REAL                  RUNKOUT       REFS        24
    0 XR           REAL        ARRAY     RUNKOUT       REFS        31        36        41        43   DEFINED        43        49
                                                           54      57
    0 X1           REAL                  RUNKOUT       REFS        24        36
    1 X2           REAL                  RUNKOUT       REFS        24
    2 X3           REAL                  RUNKOUT       REFS        24
    3 X4           REAL                  RUNKOUT       REFS        24
   10 ZDH1         REAL                  RUNKIN        REFS        15
   11 ZDH2         REAL                  RUNKIN        REFS        15
   10 ZH1          REAL                  RUNKOUT       REFS        24
   11 ZH2          REAL                  RUNKOUT       REFS        24

STATEMENT LABELS             DEF LINE    REFERENCES
   15 10                        40          39
    0 20                        43          40
   34 30                        45          39
    0 40                        49          47
   57 50                        51          39
    0 60                        54          51
   75 70                        56          39
    0 80                        57          56

LOOPS  LABEL      INDEX    FROM-TO     LENGTH     PROPERTIES
   16  20         I         40 43        14B         OPT
   43  40         I         47 49        12B         OPT
   60  60         I         51 54        13B         OPT
   76  80         I         56 57        10B         OPT
```

```
SUBROUTINE LINPLT(XT,YT1,YT2,YT3,NX,NYTS,Y1MIN,Y1MAX,
1Y2MIN,Y2MAX,Y3MIN,Y3MAX)

DESCRIPTION
    THIS ROUTINE GENERATES ON-LINE PRINTER PLOTS FOR
    1, 2, OR 3 CURVES. THE TABLE OF INDEPENDENT VARIABLES
    MUST BE EVENLY SPACED.

INPUT
    1  YT       TABLE OF INDEPENDENT VALUES. MUST BE
                EVENLY SPACED.
    2  YT1      TABLE OF DEPENDENT VALUES FOR FIRST CURVE.
    3  YT2      TABLE OF DEPENDENT VALUES FOR SECOND CURVE.
    4  YT3      TABLE OF DEPENDENT VALUES FOR THIRD CURVE.
    5  NX       NUMBER OF POINTS IN XT.
    6  NYTS     NUMBER OF CURVES TO BE PLOTTED.
                (NYTS=1, 2, OR 3)
    7  Y1MIN    LOWER LIMIT OF YT1 SCALE.
    8  Y1MAX    UPPER LIMIT OF YT1 SCALE.
                IF Y1MIN =Y1MAX , THIS ROUTINE WILL
                CALCULATE SCALE VALUES.
    9  Y2MIN    LOWER LIMIT OF YT2 SCALE.
    10 Y2MAX    UPPER LIMIT OF YT2 SCALE.
                IF Y2MIN =Y2MAX , THIS ROUTINE WILL
                CALCULATE SCALE VALUES.
    11 Y3MIN    LOWER LIMIT OF YT3 SCALE.
    12 Y3MAX    UPPER LIMIT OF YT3 SCALE.
                IF Y3MIN =Y3MAX , THIS ROUTINE WILL
                CALCULATE SCALE VALUES.

OUTPUT
    ON-LINE PRINTER PLOTS

REMARKS
    IF A PLOT OF 1 CURVE OR A PLOT OF 2 CURVES IS
    DESIRED, THE VARIABLES NOT NEEDED MUST BE DUMMY
    VARIABLES IN THE  CALL  STATEMENT.
    EXAMPLE...TO PLOT 1 CURVE
    CALL LINPLT(XV1,YV1,DUMMY,DUMMY,100,1,-1.0,1.0,0.,0.,0.,0.)
```

```
      SUBROUTINE LINPLT(XT,YT1,YT2,YT3,NX,NYTS,Y1MIN,Y1MAX,
C    1Y2MIN,Y2MAX,Y3MIN,Y3MAX)
      DIMENSION XT(1),YT1(1),YT2(1),YT3(1),WRKARR(101)
      DIMENSION TT(4),DLM(3),SCA(3),SCALE(6),ABC(3)
      DIMENSION YMIN(3),YMAX(3),YLL(3),YUL(3)
      DATA BLK,DOT/1H ,1H./
      DATA ABC/1HA,1HB,1HC/
      DATA TT /1.0,2.0,5.0,10.0 /
C         INITIALIZE
      DO 200 II=1,3
      IF(II .GT. NYTS) GO TO 300
      GO TO (10,20,30), II
   10 YMN=Y1MIN
      YMX=Y1MAX
      GO TO 50
   20 YMN=Y2MIN
      YMX=Y2MAX
      GO TO 50
   30 YMN=Y3MIN
      YMX=Y3MAX
   50 YMIN(II)=1.0E+20
      YMAX(II)=-1.0E+20
      DO 60 I=1,NX
      IF(II .EQ. 1)  Y=YT1(I)
      IF(II .EQ. 2)  Y=YT2(I)
      IF(II .EQ. 3)  Y=YT3(I)
      YMIN(II)=AMIN1(YMIN(II),Y)
   60 YMAX(II)=AMAX1(YMAX(II),Y)
      IF(YMN .EQ. YMX)   GO TO 70
      YLL(II) = YMN
      YUL(II) = YMX
      GO TO 140
C     SET SCALES
   70 D=ABS(YMAX(II)-YMIN(II))
      IF(D .NE. 0.0) GO TO 72
      D = 0.01*ABS(YMAX(II))
      IF(D .EQ. 0.0) D = 1.0
   72 L1 = ALOG10(D)
      IF(D .LT. 1.0)    L1 = L1-1
      TEST = .5*10.0**(FLOAT(L1-8))
      DO 75 I=1,4
      R = TT(I) * 10.0**FLOAT(L1)
      IF(R .GE. D)    GO TO 80
   75 CONTINUE
   80 IF(YMIN(II) .NE. 0.0) GO TO 90
      YLL(II)=0.0
      YUL(II)=R
      GO TO 140
   90 IF(YMAX(II) .NE. 0.0) GO TO 100
   95 YUL(II)=0.0
      YLL(II)=-R
      GO TO 140
  100 P=.5*(YMIN(II)+YMAX(II))
      P = P+0.001*R*SIGN(1.0,P)
      L2 = 0
```

```
      IF(P .NE. 0.0)   L2 = ALOG10(ABS(P))
      IF(ABS(P) .LT. 1.0)  L2=L2-1
      IP=(P+.5*10.0**FLOAT(L2))/10.0**FLOAT(L2)
      IF(IP .LE. 0) IP=IP-1
  110 YLL(II)=FLOAT(IP)*10.0**FLOAT(L2)-.5*R
      IF(YLL(II) .GT. YMIN(II))  GO TO 125
      IF(YMIN(II) .GT. 0.0)   YLL(II)=AMAX1(0.0,YLL(II))
      YUL(II)=YLL(II)+R
      IF(YUL(II) .LT. YMAX(II)) GO TO 135
      IF(YMAX(II) .LT. 0.0 .AND. YUL(II) .GT. 0.0) GO TO 95
      IF(YUL(II)*YLL(II) .GE. 0.0) GO TO 130
      DO 120 I=1,10
      TMP1=YLL(II)+.1*R*FLOAT(I)
      IF(ABS(TMP1) .LE. TEST) GO TO 130
  120 CONTINUE
  125 IP=IP-1
      GO TO 110
  130 IF(YUL(II) .GE. YMAX(II)) GO TO 140
      IF(YMAX(II)-YUL(II) .LE. .005*R)  GO TO 140
  135 R = 2.0*R
      GO TO 110
  140 DLM(II)=(YUL(II)-YLL(II))/5.0
      SCA(II)=YLL(II)
C     PRINT CURVE MAX AND MIN VALUES
  150 IF(II .EQ.1) WRITE(6,160)
  160 FORMAT(1H1)
      WRITE(6,170) II,ABC(II),YMIN(II),YMAX(II)
  170 FORMAT(1X,7HCURVE Y,I1,1X,10HDENOTED BY,1X,A1,4X,4HMIN=1PE10.3,
     12X,4HMAX=1PE10.3)
  200 CONTINUE
C     PRINT CURVE SCALES
  300 WRITE(6,310)
  310 FORMAT(1H0)
      DO 350 II=1,3
      IF(II .GT. NYTS) GO TO 360
      SCALE(1)=SCA(II)
      DO 320 I=2,6
      SCALE(I)=SCALE(I-1)+DLM(II)
      IF(ABS(SCALE(I)) .LT. TEST) SCALE(I) = 0.0
  320 CONTINUE
  330 WRITE(6,340) ABC(II), (SCALE(I),I=1,6)
  340 FORMAT(1X,6HSCALE ,A1,10X,1PE10.3,10X,1PE10.3,10X,1PE10.3,10X,
     11PE10.3,10X,1PE10.3,10X,1PE10.3)
  350 CONTINUE
  360 NXP=NX+10
      WRITE(6,365)
  365 FORMAT(1HT)
      DX=XT(2)-XT(1)
      DO 800 I=1,NXP
      WRKARR(1)=DOT
      DO 375 JJ=2,101
      J=JJ
      WRKARR(J)=BLK
      IF(MOD((J-1),10).EQ.0) WRKARR(J)=DOT
      IF(I.EQ.1) WRKARR(J)=DOT
```

```
      IF(MOD((I-1),5).EQ.0) WRKARR(J)=DOT
  375 CONTINUE
      IF(I.GT.NX) GO TO 760
  400 DO 420 II=1,3
      IF(II .GT. NYTS) GO TO 720
      IF(II.EQ.1) Y=YT1(I)
      IF(II.EQ.2) Y=YT2(I)
      IF(II.EQ.3) Y=YT3(I)
      NP=100*(Y-YLL(II))/(YUL(II)-YLL(II))+1.5
      IF(NP .GT. 101) NP=101
      IF(NP .LT. 1) NP=1
      WRKARR(NP)=ABC(II)
  420 CONTINUE
C          PRINT LINE OF DESIRED PLOTS
  720 X=XT(I)
      IF(I.EQ.1) GO TO 740
      IF(MOD((I-1),10).EQ.0) GO TO 740
      WRITE(6,730) WRKARR
  730 FORMAT(20X,101A1)
      GO TO 800
  740 WRITE(6,750) X,WRKARR
  750 FORMAT(10X,1PE10.3,101A1)
      GO TO 800
  760 X=XT(NX)+FLOAT(I-NX)*DX
      IF(MOD((I-1),10).EQ.0) GO TO 820
      WRITE(6,730) WRKARR
  800 CONTINUE
      GO TO 830
  820 WRITE(6,750) X,WRKARR
  830 WRITE(6,835)
  835 FORMAT(1HS)
      RETURN
      END
```

```
SUBROUTINE SESOMI(X,N,NB,MS,MN1,D,R,E,WORK,IHLD,IC,ID,IS)

DESCRIPTION
    THIS SUBROUTINE WILL SOLVE AN N BY N SYSTEM OF SIMULTANEOUS
    EQUATIONS WITH AN ARBITRARY NUMBER OF RIGHT HAND SIDES OR
    INVERT A MATRIX OF ORDER N.  IN THE PROCESS, THE RANK OF
    THE MATRIX AND ITS DETERMINANT ARE EVALUATED.  THE METHOD
    USED IS THAT OF GAUSS-JORDAN WITH TOTAL PIVOTING IF DESIRED.

INPUT
    1  X        FIRST LOCATION OF INPUT COEFFICIENT MATRIX,X(1,1)
                AUGMENTED BY NB RIGHT HAND SIDES.  FOR MATRIX
                INVERSE, X IS FIRST LOCATION OF THE MATRIX TO BE
                INVERTED.  I.E. X(1,1).  X MUST BE DIMENSIONED
                TO (MN1,MN1+NB) IN THE CALLING PROGRAM IN EITHER
                CASE.
    2  N        NUMBER OF SIMULTANEOUS EQUATIONS TO BE SOLVED,
                OR ORDER OF MATRIX TO BE INVERTED.
    3  NB       NB = NUMBER OF RIGHT HAND SIDES FOR SIMULTANEOUS
                EQUATION SOLUTION.  NB = N FOR MATRIX INVERSE.
    4  MS       MS = 0 FOR SIMULTANEOUS EQUATION SOLUTION.
                MS = 1 FOR MATRIX INVERSE.
    5  MN1      ROW DIMENSION OF X AS DEFINED IN CALLING PROGRAM.
    6  WORK     WORKING ARRAY DIMENSIONED AS FOLLOWS IN CALLING
                PROGRAM... WORK(MN1+NB).
    7  IHLD     WORKING ARRAY DIMENSIONED AS FOLLOWS IN CALLING
                PROGRAM... IHLD(MN1).
    8  IC       IC=1, PIVOTING BY ROW ONLY. NORMALLY SUFFICIENT.
                IC=0, PIVOTING BY ROW AND COLUMN. RUNS LONGER.
    9  ID       ID=1, DETERMINANT CALCUALTED.
                ID=0, DETERMINANT NOT DESIRED.
   10  IS       IS=1, MATRIX IS NOT SCALED PRIOR TO MANIPULATION.
                IS=0, EACH MATRIX ELEMENT IS SCALED PRIOR TO MANIP.

OUTPUT
    1  X        X(1,1) THROUGH X(N,1) CONTAIN FIRST SOLUTION
                VECTOR.  X(1,2) THROUGH X(N,2) CONTAIN SECOND
                SOLUTION VECTOR, ETC.  FOR MATRIX INVERSE, THE
                ARRAY X CONTAINS THE INVERSE MATRIX.
    2  D        DETERMINANT OF INPUT X.
    3  R        RANK OF INPUT X.
    4  E        ERROR CHECK
                E=0 O.K.
                E=1 MATRIX OF COEFFICIENTS IS SINGULAR.
                E=2 SOLUTION IS ATTEMPTED BUT EQUATIONS MAY BE
                    SINGULAR OR ILL CONDITIONED.

REMARKS
    THIS SUBROUTINE WILL RUN FASTER WITH IC=1 AND IS=1. THE VALUE
    IC SHOULD BE SET TO 0 ONLY IN RARE CASES WHERE EXTREME ILL-
    CONDITIONING IS EVIDENT AND IS SHOULD BE SET TO 0 ONLY WHEN
    ELEMENTS OF ONE ROW OF THE MATRIX IS MUCH GREATER THAN THE
    ELEMENTS OF OTHER ROWS, CAUSING A FALSE E=2., INDICATOR.
```

```
      SUBROUTINE SESOMI(X,N,NB,MS,MN1,D,R,E,WORK,IHLD,IC,ID,IS)
      DIMENSION X(MN1,1),WORK(1),IHLD(1)
      DOUBLE PRECISION X,WORK,Y,D,SUM,X1
C     THE FOLLOWING 9 CARDS ARE TEMPORARY MODIFICATIONS TO ALLOW
C     EXISTING CALLS TO SESOMI (USING 10 ARGUMENTS) TO WORK PROPERLY.
C     ANY CALLS NOW MADE SHOULD INCLUDE ALL 13 ARGUMENTS.
      J = LOCF(IC)
      IF(J .GT. 64 )GO TO 50
      IIC = 0
      IID = 1
      IIS = 0
      GO TO 51
   50 IIC = IC
      IID = ID
      IIS = IS
   51 X1 = 1.
      E=0.
      R=0.
      IF(IIC .NE. 0)GO TO 211
      DO 21 I=1,N
   21 IHLD(I)=I
  211 CONTINUE
      IF(MS)6,4,6
    6 NN=N+N
      NB=N
      MN=N+1
      DO 14 I=1,N
      DO 14 J=MN,NN
   14 X(I,J)=0.
      DO 15 I=1,N
      J=I+N
   15 X(I,J)=1.
      GO TO 16
    4 NN=N+NB
   16 JJ=NN
      NNN=N-1
      D=0.
      IF(IID .NE. 0)D=1.
      IF(IIS .NE. 0)GO TO 361
      DO 36 I=1,N
      Y=X(I,1)
      DO 35 J=2,N
      IF(ABS(Y).LT.ABS(X(I,J)))Y=X(I,J)
   35 CONTINUE
      D=D*Y
      DO 36 J=1,NN
   36 X(I,J)=X(I,J)/Y
  361 CONTINUE
      DO 5 I=1,N
      KK=N-I
      IF(KK)10,10,26
   26 IF(IIC .NE. 0)GO TO 261
      LL=KK+1
      IJJ=1
      L=I
```

```
      WORK(1)=X(1,1)
      DO 17 II=1,LL
      DO 17 J=1,LL
      IF(ABS(WORK(1))-ABS(X(II,J)))18,17,17
   18 WORK(1)=X(II,J)
      L=J+I-1
      IJJ=J
   17 CONTINUE
      IF(IJJ-1)2,2,19
   19 DO 20 II=1,N
      Y=X(II,1)
      X(II,1)=X(II,IJJ)
   20 X(II,IJJ)=Y
      IY=IHLD(I)
      IHLD(I)=IHLD(L)
      IHLD(L)=IY
      D=-D
  261 IJJ=1
      Y=X(1,1)
    2 DO 1 L=1,KK
      IF(ABS(Y)-ABS(X(L+1,1)))7,1,1
    7 IJJ=L+1
      Y=X(L+1,1)
    1 CONTINUE
      IF(IJJ.EQ.1) GO TO 10
      D=-D
      DO 9 J=1,JJ
      Y=X(1,J)
      X(1,J)=X(IJJ,J)
    9 X(IJJ,J)=Y
   10 JJ=JJ-1
      D=D*X(1,1)
      IF(X(1,1).EQ.0.)GO TO 8
   31 IF(ABS(ABS((X1-X(1,1))/X1)-1.).LT.1.E-7)E=2.
      X1=X(1,1)
   11 R=R+1.
      DO 12 J=1,JJ
   12 WORK(J)=X(1,J+1)/X(1,1)
      KK=JJ+1
      IF(NNN.EQ.0)GO TO 33
      DO 3 K=1,NNN
      DO 3 J=2,KK
    3 X(K,J-1)=X(K+1,J)-X(K+1,1)*WORK(J-1)
   33 DO 5 J=1,JJ
    5 X(N,J)=WORK(J)
      IF(IIC .NE. 0)GO TO 13
      NN=N-1
      IF(NN.EQ.0)GO TO 13
      DO 22 I=1,NN
      L=I+1
      DO 22 J=L,N
      IF(IHLD(I)-IHLD(J))22,22,23
   23 IY=IHLD(I)
      IHLD(I)=IHLD(J)
      IHLD(J)=IY
```

```
      DO 25 K=1,NB
      Y=X(I,K)
      X(I,K)=X(J,K)
   25 X(J,K)=Y
   22 CONTINUE
   13 RETURN
    8 E=1.
      RETURN
      END
```

APPENDIX B

SAMPLE RUNS

Several complete sample runs are presented in this Appendix in order to furnish examples of the output which results when this program is run on a stand-alone basis. The plant used for the examples is a simplified autopilot loop described by aerodynamic transfer function and compensator data taken at various times along a nominal trajectory (see Reference 7). For each case, the NAMELIST input section, the $\underline{X}_m$ matrix (before and after inversion), output data as listed in Table 3, and line printer plots showing output Y and disturbance state estimates $\hat{z}_1$, $\hat{z}_2$ are given.

The disturbances used in each run are as follows:

(a) Run 1: $w(t) = 1.$

(b) Run 2: $w(t) = 1. + 0.5t$

(c) Run 3: $w(t) = 1.5 + 0.5e^{.25t}$

For runs (a) and (b), where the disturbance is of the form $w(t) = C_o + C_1 t$, the disturbance is modeled as

$$\underline{w} = \underline{H}\,\underline{z} = (1,\ 0)\begin{pmatrix} z_1 \\ z_2 \end{pmatrix}$$

$$\underline{\dot{z}} = \underline{D}\,\underline{z} + \underline{\sigma} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}\begin{pmatrix} z_1 \\ z_2 \end{pmatrix} + \underline{\sigma}.$$

For run (c), the disturbance is of the form $w(t) = Co + c_1 e^{\alpha t}$ and is modeled as

$$\underline{w} = (1,\ 0)\begin{pmatrix} z_1 \\ z_2 \end{pmatrix}$$

$$\underline{\dot{z}} = \begin{bmatrix} 0 & 1 \\ 0 & \alpha \end{bmatrix}\begin{pmatrix} z_1 \\ z_2 \end{pmatrix} + \underline{\sigma}.$$

RUN 1

```
*****************************************************************************************

$INP     RUN #1, INPUT

A        = .2E+02, .144E+02, -.1712E+04, -.856E+04, .1325916E+02, .5066242E+02,  .6554036E+02, .271441E+02,

C        = -.78847E-02,

C0       = .1E+01,

C1       = 0.0,

D        = 0.0, 0.0, .1E+01, 0.0,

H        = .1E+01, 0.0,

LM       = (-.3E+01,0.0), (-.4E+01,0.0), (-.7E+01,.2E+01), (-.7E+01,.2E+01),     (-.8E+01,0.0),
           (-.1E+02,0.0),

NPRT     = 128,

NUMBR    = 4,

NX       = 10,

PGO      = .1E+01,

STPSZ    = .32E+02,

TSTOP    = .1E+02,

$END
```

```
T(1)=-.320000E+02   .400000E+01   T(2)=-.250000E+02   .200000E+01   T(3)=-.180000E+02  0.
T(4)=-.140000E+02   .400000E+01   T(5)=-.700000E+01  0.

A(1)=-.390000E+02 A(2)= .613000E+03 A(3)=-.495300E+04 A(4)= .216340E+05 A(5)=-.483600E+05 A(6)= .432000E+05

AM( 1)=-.788470E-02 AM( 2)=0.            AM( 3)=-.132592E+02 AM( 4)=0.            AM( 5)= .157694E+00

AM( 6)= .788470E-02 AM( 7)= .506624E+02 AM( 8)=0.            AM( 9)=0.            AM(10)= .113540E+00

AM(11)= .157694E+00 AM(12)= .655404E+02 AM(13)=0.            AM(14)=0.            AM(15)=-.134986E+02

AM(16)= .113540E+00 AM(17)= .271441E+02 AM(18)=0.            AM(19)=0.            AM(20)=-.674930E+02

AM(21)=-.134986E+02 AM(22)=0.            AM(23)=0.            AM(24)=0.            AM(25)=-.674930E+02

AM(26)=0.

R(1)=-.257408E+02 R(2)= .562338E+03 R(3)= .488746E+04 R(4)= .216069E+05 R(5)= .483600E+05 R(6)= .432000E+05

XM(1,1)= .100000E+01 XM(1,2)=0.           XM(1,3)=0.           XM(1,4)=0.           XM(1,5)=-.788470E-02 XM(1,6)=0.

XM(2,1)=0.           XM(2,2)=-.100000E+01 XM(2,3)=0.           XM(2,4)=0.           XM(2,5)= .157694E+00 XM(2,6)= .788470E-02

XM(3,1)=0.           XM(3,2)=0.           XM(3,3)=-.100000E+01 XM(3,4)=0.           XM(3,5)= .113540E+00 XM(3,6)= .157694E+00

XM(4,1)=0.           XM(4,2)=0.           XM(4,3)=0.           XM(4,4)=-.100000E+01 XM(4,5)=-.134986E+02 XM(4,6)= .113540E+00

XM(5,1)=0.           XM(5,2)=0.           XM(5,3)=0.           XM(5,4)=0.           XM(5,5)=-.674930E+02 XM(5,6)=-.134986E+02

XM(6,1)=0.           XM(6,2)=0.           XM(6,3)=0.           XM(6,4)=0.           XM(6,5)=0.           XM(6,6)=-.674930E+02

XM(1,1)= .100000E+01 XM(1,2)=0.           XM(1,3)=0.           XM(1,4)=0.           XM(1,5)=-.116822E-03 XM(1,6)= .233645E-04

XM(2,1)=0.           XM(2,2)=-.100000E+01 XM(2,3)=0.           XM(2,4)=0.           XM(2,5)=-.233645E-02 XM(2,6)= .350467E-03

XM(3,1)=0.           XM(3,2)=0.           XM(3,3)=-.100000E+01 XM(3,4)=0.           XM(3,5)=-.168224E-02 XM(3,6)=-.200000E-02

XM(4,1)=0.           XM(4,2)=0.           XM(4,3)=0.           XM(4,4)=-.100000E+01 XM(4,5)= .200000E+00 XM(4,6)=-.416822E-01

XM(5,1)=0.           XM(5,2)=0.           XM(5,3)=0.           XM(5,4)=0.           XM(5,5)=-.148163E-01 XM(5,6)= .296327E-02

XM(6,1)=0.           XM(6,2)=0.           XM(6,3)=0.           XM(6,4)=0.           XM(6,5)=0.           XM(6,6)=-.148163E-01


   DET= -.4555309E+04    RA=  .6000000E+01    E= 0.

K(1)=-.303810E+02 K(2)=-.660188E+03 K(3)=-.505521E+04 K(4)=-.137355E+05 K(5)=-.588505E+03 K(6)=-.640066E+03

   TIME = 0.           XD1  = 0.           XD2  = 0.           XD3  = 0.           XD4  = 0.
   X1   = 0.           X2   = 0.           X3   = 0.           X4   = 0.           XDH1 = 0.
   XDH2 = 0.           XDH3 = 0.           XDH4 = 0.           ZDH1 = 0.           ZDH2 = 0.
   XH1  = 0.           XH2  = 0.           XH3  = 0.           XH4  = 0.           ZH1  = 0.
   ZH2  = 0.           PGO  =  .1000000E+01 W   = 0.           UDA  = 0.           Y    = 0.
```

```
TIME =  .1000000E+01   XD1  =  .6079224E+00   XD2  =  .6632977E+01   XD3  =  .1400536E+02   XD4  = -.1375048E+02
X1   =  .6423598E+00   X2   =  .9022833E+01   X3   =  .3874161E+02   X4   =  .5483239E+02   XDH1 =  .4965632E+00
XDH2 =  .4795033E+01   XDH3 =  .9727668E+00   XDH4 = -.4847177E+02   ZDH1 = -.1659993E+01   ZDH2 = -.2596457E+01
XH1  =  .6454718E+00   XH2  =  .9193399E+01   XH3  =  .3993056E+02   XH4  =  .5813855E+02   ZH1  =  .1288801E+01
ZH2  =  .6980323E+00   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1315429E+01   Y    =  .6402085E+00


TIME =  .2000000E+01   XD1  = -.1412598E+00   XD2  = -.1887715E+01   XD3  = -.7617743E+01   XD4  = -.8006926E+01
X1   =  .7642982E+00   X2   =  .1002667E+02   X3   =  .3687482E+02   X4   =  .3995333E+02   XDH1 = -.1205505E+00
XDH2 = -.1617378E+01   XDH3 = -.5666908E+01   XDH4 = -.2863760E+01   ZDH1 =  .1687666E+00   ZDH2 =  .9170375E-01
XH1  =  .7651376E+00   XH2  =  .1003512E+02   XH3  =  .3701793E+02   XH4  =  .4057109E+02   ZH1  =  .1051940E+01
ZH2  =  .9058734E-01   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1046360E+01   Y    =  .7631598E+00


TIME =  .3000000E+01   XD1  = -.2470653E-01   XD2  = -.1539012E+00   XD3  =  .9330406E+00   XD4  =  .4756761E+01
X1   =  .6632571E+00   X2   =  .8791909E+01   X3   =  .3337036E+02   X4   =  .3971393E+02   XDH1 = -.1967491E-01
XDH2 = -.5712742E-01   XDH3 =  .1546517E+01   XDH4 =  .6260982E+01   ZDH1 =  .5932165E-01   ZDH2 =  .6106235E-01
XH1  =  .6633364E+00   XH2  =  .8791295E+01   XH3  =  .3339693E+02   XH4  =  .3981397E+02   ZH1  =  .1004019E+01
ZH2  =  .4603071E-02   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1002723E+01   Y    =  .6606956E+00


TIME =  .4000000E+01   XD1  =  .5884867E-01   XD2  =  .7250972E+00   XD3  =  .2454174E+01   XD4  =  .1843567E+01
X1   =  .6960306E+00   X2   =  .9293857E+01   X3   =  .3586016E+02   X4   =  .4373116E+02   XDH1 =  .4908556E-01
XDH2 =  .5759456E+00   XDH3 =  .1378225E+01   XDH4 = -.1069909E+01   ZDH1 = -.1260938E+00   ZDH2 = -.1385628E+00
XH1  =  .6959843E+00   XH2  =  .9299099E+01   XH3  =  .3587676E+02   XH4  =  .4373348E+02   ZH1  =  .9988082E+00
ZH2  = -.1363391E-02   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1001237E+01   Y    =  .6934624E+00


TIME =  .5000000E+01   XD1  =  .6638800E-02   XD2  =  .3952231E-01   XD3  = -.2678063E+00   XD4  = -.1282243E+01
X1   =  .7289146E+00   X2   =  .9684745E+01   X3   =  .3688508E+02   X4   =  .4366933E+02   XDH1 =  .5234748E-02
XDH2 =  .1189737E-01   XDH3 = -.4448506E+00   XDH4 = -.1725676E+01   ZDH1 = -.1667377E-01   ZDH2 = -.2062317E-01
XH1  =  .7289362E+00   XH2  =  .9685282E+01   XH3  =  .3688128E+02   XH4  =  .4365440E+02   ZH1  =  .9997393E+00
ZH2  =  .8586540E-04   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1000091E+01   Y    =  .7267356E+00


TIME =  .6000000E+01   XD1  = -.1532339E-01   XD2  = -.1880282E+00   XD3  = -.6285549E+00   XD4  = -.4487033E+00
X1   =  .7201474E+00   X2   =  .9550771E+01   X3   =  .3622589E+02   X4   =  .4262903E+02   XDH1 = -.1277760E-01
XDH2 = -.1490362E+00   XDH3 = -.3477320E+00   XDH4 =  .3106168E+00   ZDH1 =  .3282118E-01   ZDH2 =  .3601964E-01
XH1  =  .7201550E+00   XH2  =  .9549421E+01   XH3  =  .3622180E+02   XH4  =  .4262920E+02   ZH1  =  .1000341E+01
ZH2  =  .4000739E-03   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .9997073E+00   Y    =  .7179584E+00


TIME =  .7000000E+01   XD1  = -.1372468E-02   XD2  = -.5982773E-02   XD3  =  .8355972E-01   XD4  =  .3422791E+00
X1   =  .7118403E+00   X2   =  .9452724E+01   X3   =  .3597556E+02   X4   =  .4266852E+02   XDH1 = -.1066562E-02
XDH2 =  .2864169E-03   XDH3 =  .1230360E+00   XDH4 =  .4399186E+00   ZDH1 =  .4089254E-02   ZDH2 =  .4568886E-02
XH1  =  .7118422E+00   XH2  =  .9452616E+01   XH3  =  .3597664E+02   XH4  =  .4267241E+02   ZH1  =  .1000062E+01
ZH2  = -.2737033E-04   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .9998849E+00   Y    =  .7095557E+00


TIME =  .8000000E+01   XD1  =  .4001100E-02   XD2  =  .4885060E-01   XD3  =  .1609761E+00   XD4  =  .1085754E+00
X1   =  .7143004E+00   X2   =  .9489646E+01   X3   =  .3615198E+02   X4   =  .4293716E+02   XDH1 =  .3334501E-02
XDH2 =  .3860712E-01   XDH3 =  .8732892E-01   XDH4 = -.9035699E-01   ZDH1 = -.8596019E-02   ZDH2 = -.9436067E-02
XH1  =  .7142971E+00   XH2  =  .9489998E+01   XH3  =  .3615342E+02   XH4  =  .4293703E+02   ZH1  =  .9999165E+00
ZH2  = -.1025433E-03   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1000076E+01   Y    =  .7120193E+00
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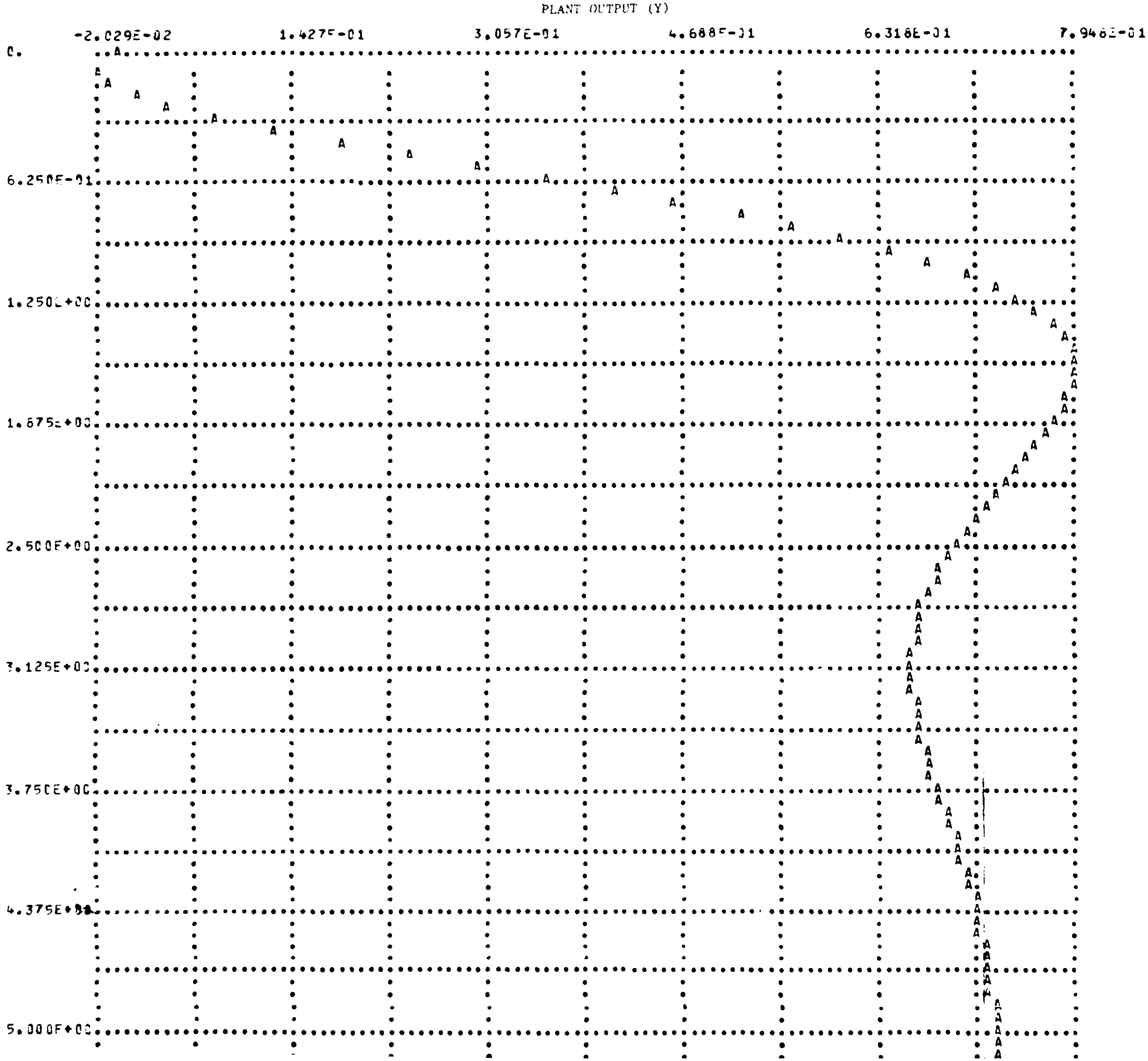
TIME =  .9000000E+01   XD1  =  .2659585E-03   XD2  =  .4558970E-03   XD3  = -.2525314E-01   XD4  = -.9110542E-01
X1   =  .7163962E+00   X2   =  .9514221E+01   X3   =  .3621288E+02   X4   =  .4292091E+02   XDH1 =  .2016352E-03
XDH2 = -.9388876E-03   XDH3 = -.3383116E-01   XDH4 = -.1119466E+00   ZDH1 = -.8669565E-03   ZDH2 = -.9724571E-03
XH1  =  .7163958E+00   XH2  =  .9514241E+01   XH3  =  .3621258E+02   XH4  =  .4291991E+02   ZH1  =  .9999861E+00
ZH2  =  .9437232E-05   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .1000002E+01   Y    =  .7141412E+00

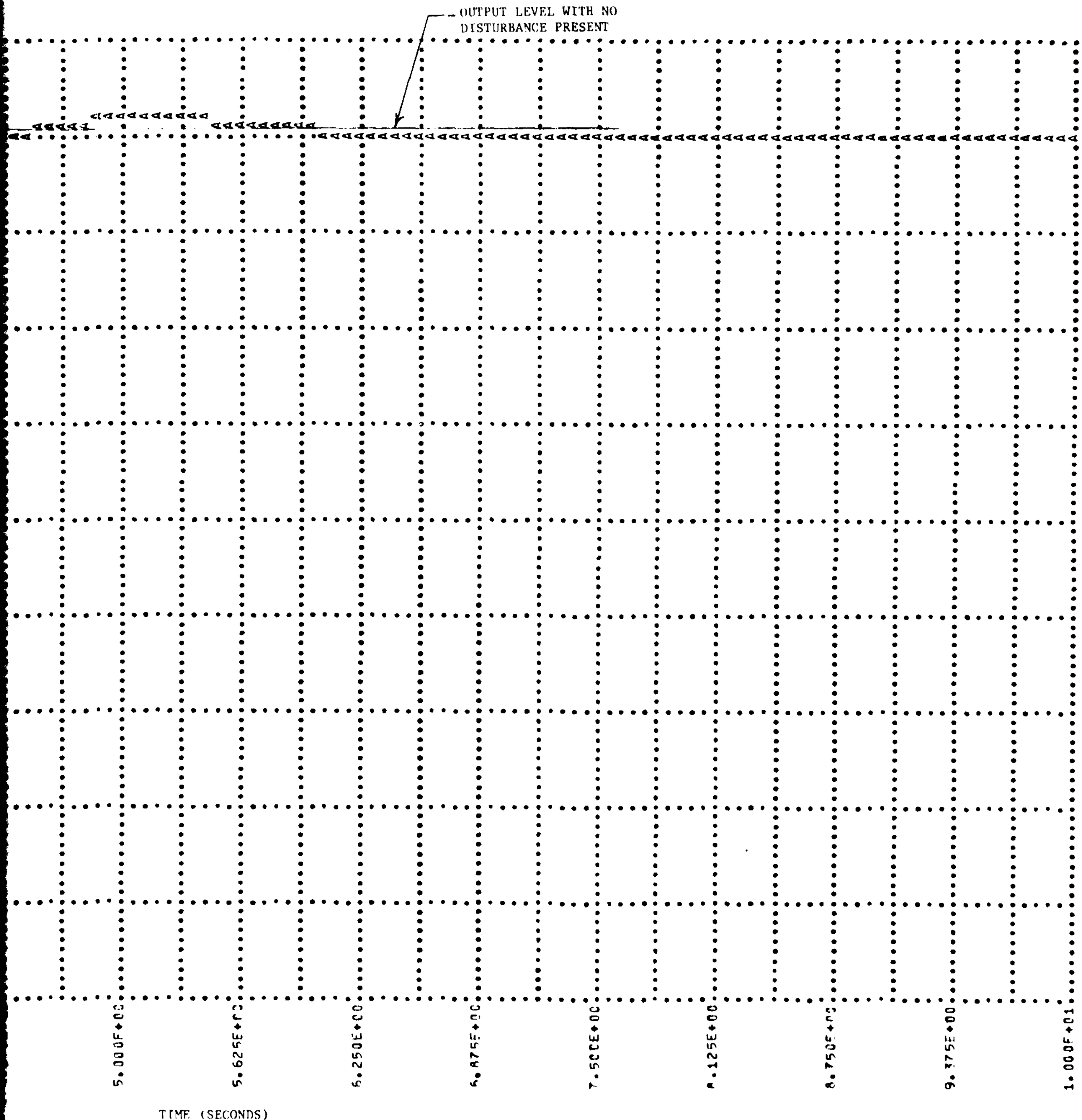

TIME =  .1000000E+02   XD1  = -.1042501E-02   XD2  = -.1266567E-01   XD3  = -.4113742E-01   XD4  = -.2606685E-01
X1   =  .7157120E+00   X2   =  .9504105E+01   X3   =  .3616582E+02   X4   =  .4285168E+02   XDH1 = -.8603683E-03
XDH2 = -.9980703E-02   XDH3 = -.2186590E-01   XDH4 =  .2591632E-01   ZDH1 =  .2246341E-02   ZDH2 =  .2466327E-02
XH1  =  .7157128E+00   XH2  =  .9504014E+01   XH3  =  .3616555E+02   XH4  =  .4285174E+02   ZH1  =  .1000024E+01
ZH2  =  .2635707E-04   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .9999802E+00   Y    =  .7134554E+00


TIME =  .1000000E+02   XD1  = -.1042501E-02   XD2  = -.1266567E-01   XD3  = -.4113742E-01   XD4  = -.2606685E-01
X1   =  .7157123E+00   X2   =  .9504105E+01   X3   =  .3616592E+02   X4   =  .4285168E+02   XDH1 = -.8603683E-03
XDH2 = -.9980703E-02   XDH3 = -.2186590E-01   XDH4 =  .2591632E-01   ZDH1 =  .2246341E-02   ZDH2 =  .2466327E-02
XH1  =  .7157128E+00   XH2  =  .9504014E+01   XH3  =  .3616555E+02   XH4  =  .4285174E+02   ZH1  =  .1000024E+01
ZH2  =  .2635707E-04   PGO  =  .1000000E+01   W    =  .1000000E+01   UDA  =  .9999802E+00   Y    =  .7134554E+00
```

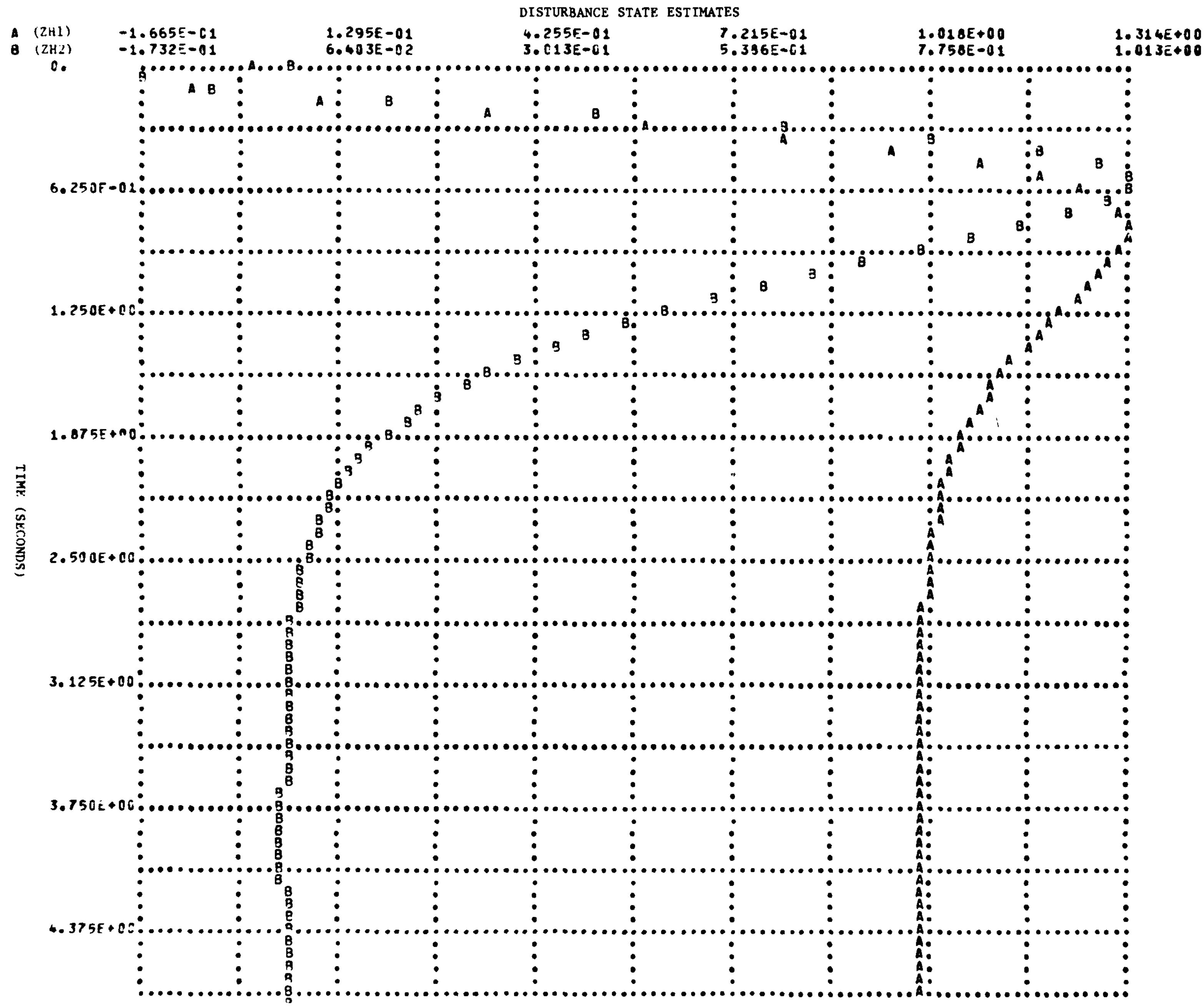
CURVE Y1 DENOTED BY A   MIN=-2.029E-02 MAX= 7.948E-01

SCALE A




OUTPUT LEVEL WITH NO DISTURBANCE PRESENT
5.000E+00
5.625E+00
6.250E+00
6.875E+00
7.500E+00
8.125E+00
8.750E+00
9.375E+00
1.000E+01
TIME (SECONDS)

CURVE Y1 DENOTED BY A MIN=-1.665E-01 MAX= 1.314E+00
CURVE Y2 DENOTED BY B MIN=-1.732E-01 MAX= 1.013E+00



RUN 2

```
-----------------------------------------------------------------------------------------------

$INP    RUN #1, INPUT

B       = .2E+02, -.44E+03, -.108E+05, -.54E+05, .176816E+02, .2437748E+03,     .4385048E+03, .211-116E+03,

C       = -.3328E-01,

C0      = .1E+01,

C1      = .5E+00,

D       = 0.0, 0.0, .1E+01, 0.0,

H       = .1E+01, 0.0,

LM      = (-.5E+01,0.0), (-.6E+01,0.0), (-.1E+02,0.0), (-.1E+02,0.0),          (-.12E+02,0.0),
          (-.15E+02,0.0),

NPRT    = 128,

NUMBP   = 4,

NX      = 10,

PGO     = .1E+01,

STPSZ   = .32E+02,

TSTOP   = .1E+02,

$END
```

```
T(1)=-.470000E+02  0.             T(2)=-.370000E+02  0.             T(3)=-.270000E+02  0.
T(4)=-.200000E+02  0.             T(5)=-.110000E+02  0.

A(1)=-.580000E+02 A(2)= .136700E+04 A(3)=-.167300E+05 A(4)= .111900E+06 A(5)=-.387000E+06 A(6)= .540000E+06

AM( 1)=-.332800E-01 AM( 2)=0.            AM( 3)=-.176816E+02 AM( 4)=0.            AM( 5)= .665600E+00

AM( 6)= .332800E-01 AM( 7)= .243775E+03 AM( 8)=0.            AM( 9)=0.            AM(10)=-.146432E+02

AM(11)= .665600E+00 AM(12)= .438505E+03 AM(13)=0.            AM(14)=0.            AM(15)=-.359424E+03

AM(16)=-.146432E+02 AM(17)= .211412E+03 AM(18)=0.            AM(19)=0.            AM(20)=-.179712E+04

AM(21)=-.359424E+03 AM(22)=0.            AM(23)=0.            AM(24)=0.            AM(25)=-.179712E+04

AM(26)=0.

R(1)=-.403184E+02 R(2)= .112323E+04 R(3)= .162915E+05 R(4)= .111689E+06 R(5)= .387000E+06 R(6)= .540000E+06

XM(1,1)= .100000E+01 XM(1,2)=0.            XM(1,3)=0.            XM(1,4)=0.            XM(1,5)=-.332800E-01 XM(1,6)=0.

XM(2,1)=0.            XM(2,2)=-.100000E+01 XM(2,3)=0.            XM(2,4)=0.            XM(2,5)= .665600E+00 XM(2,6)= .332800E-01

XM(3,1)=0.            XM(3,2)=0.            XM(3,3)=-.100000E+01 XM(3,4)=0.            XM(3,5)=-.146432E+02 XM(3,6)= .665600E+00

XM(4,1)=0.            XM(4,2)=0.            XM(4,3)=0.            XM(4,4)=-.100000E+01 XM(4,5)=-.359424E+03 XM(4,6)=-.146432E+02

XM(5,1)=0.            XM(5,2)=0.            XM(5,3)=0.            XM(5,4)=0.            XM(5,5)=-.179712E+04 XM(5,6)=-.359424E+03

XM(6,1)=0.            XM(6,2)=0.            XM(6,3)=0.            XM(6,4)=0.            XM(6,5)=0.            XM(6,6)=-.179712E+04

XM(1,1)= .100000E+01 XM(1,2)=0.            XM(1,3)=0.            XM(1,4)=0.            XM(1,5)=-.185185E-04 XM(1,6)= .370370E-05

XM(2,1)=0.            XM(2,2)=-.100000E+01 XM(2,3)=0.            XM(2,4)=0.            XM(2,5)=-.370370E-03 XM(2,6)= .555556E-04

XM(3,1)=0.            XM(3,2)=0.            XM(3,3)=-.100000E+01 XM(3,4)=0.            XM(3,5)= .814815E-02 XM(3,6)=-.200000E-02

XM(4,1)=0.            XM(4,2)=0.            XM(4,3)=0.            XM(4,4)=-.100000E+01 XM(4,5)= .200000E+00 XM(4,6)=-.318519E-01

XM(5,1)=0.            XM(5,2)=0.            XM(5,3)=0.            XM(5,4)=0.            XM(5,5)=-.556446E-03 XM(5,6)= .111289E-03

XM(6,1)=0.            XM(6,2)=0.            XM(6,3)=0.            XM(6,4)=0.            XM(6,5)=0.            XM(6,6)=-.556446E-03


   DET= -.3229640E+07   RA=  .6000000E+01   E= 0.

K(1)=-.454851E+02 K(2)=-.123656E+04 K(3)=-.142182E+05 K(4)=-.514886E+05 K(5)=-.155248E+03 K(6)=-.333481E+03

  TIME = 0.          XD1  = 0.             XD2  = 0.          XD3  = 0.          XD4  = 0.
  X1   = 0.          X2   = 0.             X3   = 0.          X4   = 0.          XDH1 = 0.
  XH2  = 0.          XDH3 = 0.             XDH4 = 0.          ZDH1 = 0.          ZDH2 = 0.
  XH1  = 0.          XH2  = 0.             XH3  = 0.          XH4  = 0.          ZH1  = 0.
  ZH2  = 0.          PGO  =  .1000000E+01  W    = 0.          UDA  = 0.          Y    = 0.
```

```
TIME =  .1000000E+01   XD1  = -.3110706E+00   XD2  = -.5267632E+01   XD3  = -.7779523E+02   XD4  = -.2118939E+03
X1   =  .9280659E+00   X2   =  .1616113E+02   X3   =  .2222104E+03   X4   =  .3341483E+03   XDH1 = -.2426589E+00
XDH2 = -.3576046E+01   XDH3 = -.6288625E+02   XDH4 = -.1590423E+03   ZDH1 =  .5096986E+00   ZDH2 = -.4845186E+00
XH1  =  .9344028E+00   XH2  =  .1637174E+02   XH3  =  .2247700E+03   XH4  =  .3456251E+03   ZH1  =  .1580386E+01
ZH2  =  .7699491E+00   PGO  =  .1000000E+01   W    =  .1500000E+01   UDA  =  .1575371E+01   Y    =  .9291772E+00

TIME =  .2000000E+01   XD1  =  .8492381E-01   XD2  =  .1448084E+01   XD3  =  .1975917E+02   XD4  =  .4830117E+02
X1   =  .8793473E+00   X2   =  .1562612E+02   X3   =  .2126739E+03   X4   =  .3578829E+03   XDH1 =  .6172443E-01
XDH2 =  .7923703E+00   XDH3 =  .1323198E+02   XDH4 =  .1687306E+02   ZDH1 =  .4266095E+00   ZDH2 = -.1430763E+00
XH1  =  .8792531E+00   XH2  =  .1563597E+02   XH3  =  .2128274E+03   XH4  =  .3581694E+03   ZH1  =  .1999117E+01
ZH2  =  .4979180E+00   PGO  =  .1000000E+01   W    =  .2000000E+01   UDA  =  .2000441E+01   Y    =  .8749466E+00

TIME =  .3000000E+01   XD1  = -.1445108E-01   XD2  = -.2625927E+00   XD3  = -.3615202E+01   XD4  = -.1116329E+02
X1   =  .9033990E+00   X2   =  .1596963E+02   X3   =  .2177414E+03   X4   =  .3553265E+03   XDH1 = -.1076838E-01
XDH2 = -.1628931E+00   XDH3 = -.2638285E+01   XDH4 = -.7438893E+01   ZDH1 =  .5113105E+00   ZDH2 =  .2116658E-01
XH1  =  .9834218E+00   XH2  =  .1596826E+02   XH3  =  .2177163E+03   XH4  =  .3552581E+03   ZH1  =  .2500237E+01
ZH2  =  .5007838E+00   PGO  =  .1000000E+01   W    =  .2500000E+01   UDA  =  .2500025E+01   Y    =  .9001156E+00

TIME =  .4000000E+01   XD1  =  .1864373E-02   XD2  =  .3601191E-01   XD3  =  .5270227E+00   XD4  =  .2468038E+01
X1   =  .8976808E+00   X2   =  .1587154E+02   X3   =  .2162947E+03   X4   =  .3540633E+03   XDH1 =  .1443179E-02
XDH2 =  .2759861E-01   XDH3 =  .4277657E+00   XDH4 =  .2051724E+01   ZDH1 =  .4986647E+00   ZDH2 = -.2417530E-02
XH1  =  .8970788E+00   XH2  =  .1587175E+02   XH3  =  .2162990E+03   XH4  =  .3540826E+03   ZH1  =  .2999978E+01
ZH2  =  .4998662E+00   PGO  =  .1000000E+01   W    =  .3000000E+01   UDA  =  .3000002E+01   Y    =  .8935334E+00

TIME =  .5000000E+01   XD1  = -.8462174E-04   XD2  = -.3143971E-02   XD3  = -.4471175E-01   XD4  = -.4645352E+00
X1   =  .8984789E+00   X2   =  .1589444E+02   X3   =  .2166317E+03   X4   =  .3546580E+03   XDH1 = -.8397436E-04
XDH2 = -.3510325E-02   XDH3 = -.4937732E-01   XDH4 = -.4675960E+00   ZDH1 =  .5000137E+00   ZDH2 =  .4261572E-05
XH1  =  .8984707E+00   XH2  =  .1589442E+02   XH3  =  .2166311E+03   XH4  =  .3546535E+03   ZH1  =  .3499998E+01
ZH2  =  .5000163E+00   PGO  =  .1000000E+01   W    =  .3500000E+01   UDA  =  .3499998E+01   Y    =  .8949756E+00

TIME =  .6000000E+01   XD1  = -.4977684E-04   XD2  = -.4631205E-03   XD3  = -.5984299E-02   XD4  =  .7121517E-01
X1   =  .8982104E+00   X2   =  .1588988E+02   X3   =  .2165648E+03   X4   =  .3544828E+03   XDH1 = -.3134612E-04
XDH2 =  .1412873E-03   XDH3 =  .2334211E-03   XDH4 =  .9087346E-01   ZDH1 =  .5000520E+00   ZDH2 =  .1056317E-03
XH1  =  .8982106E+00   XH2  =  .1588988E+02   XH3  =  .2165648E+03   XH4  =  .3544837E+03   ZH1  =  .4000002E+01
ZH2  =  .4999996E+00   PGO  =  .1000000E+01   W    =  .4000000E+01   UDA  =  .4000001E+01   Y    =  .8947065E+00

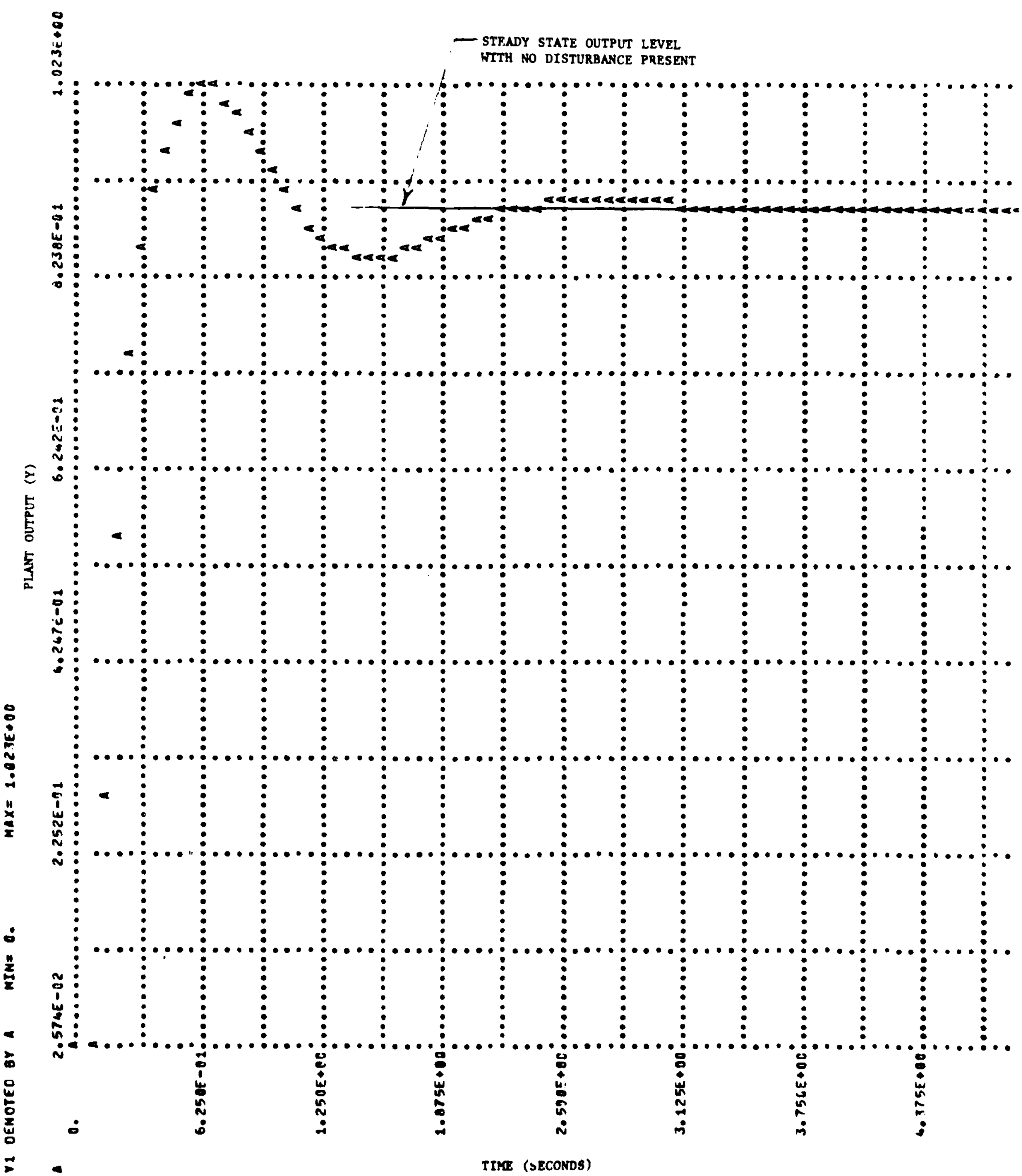
TIME =  .7000000E+01   XD1  =  .2311190E-04   XD2  =  .3195487E-03   XD3  =  .4310338E-02   XD4  = -.7894614E-02
X1   =  .8982501E+00   X2   =  .1589064E+02   X3   =  .2165758E+03   X4   =  .3545246E+03   XDH1 =  .1591521E-04
XDH2 =  .1807334E-03   XDH3 =  .2099094E-02   XDH4 = -.1460426E-01   ZDH1 =  .4999790E+00   ZDH2 = -.4127075E-04
XH1  =  .8982500E+00   XH2  =  .1589064E+02   XH3  =  .2165758E+03   XH4  =  .3545244E+03   ZH1  =  .4499999E+01
ZH2  =  .4999994E+00   PGO  =  .1000000E+01   W    =  .4500000E+01   UDA  =  .4500000E+01   Y    =  .8947472E+00

TIME =  .8000000E+01   XD1  = -.6780962E-05   XD2  = -.1037378E-03   XD3  = -.1410950E-02   XD4  = -.3991723E-03
X1   =  .8982462E+00   X2   =  .1589055E+02   X3   =  .2165745E+03   X4   =  .3545161E+03   XDH1 = -.4799465E-05
XDH2 = -.4544274E-04   XDH3 = -.8267198E-03   XDH4 =  .1649596E-02   ZDH1 =  .5000059E+00   ZDH2 =  .1136604E-04
XH1  =  .8982462E+00   XH2  =  .1589055E+02   XH3  =  .2165745E+03   XH4  =  .3545161E+03   ZH1  =  .5000000E+01
ZH2  =  .5000002E+00   PGO  =  .1000000E+01   W    =  .5000000E+01   UDA  =  .5000000E+01   Y    =  .8947433E+00
```

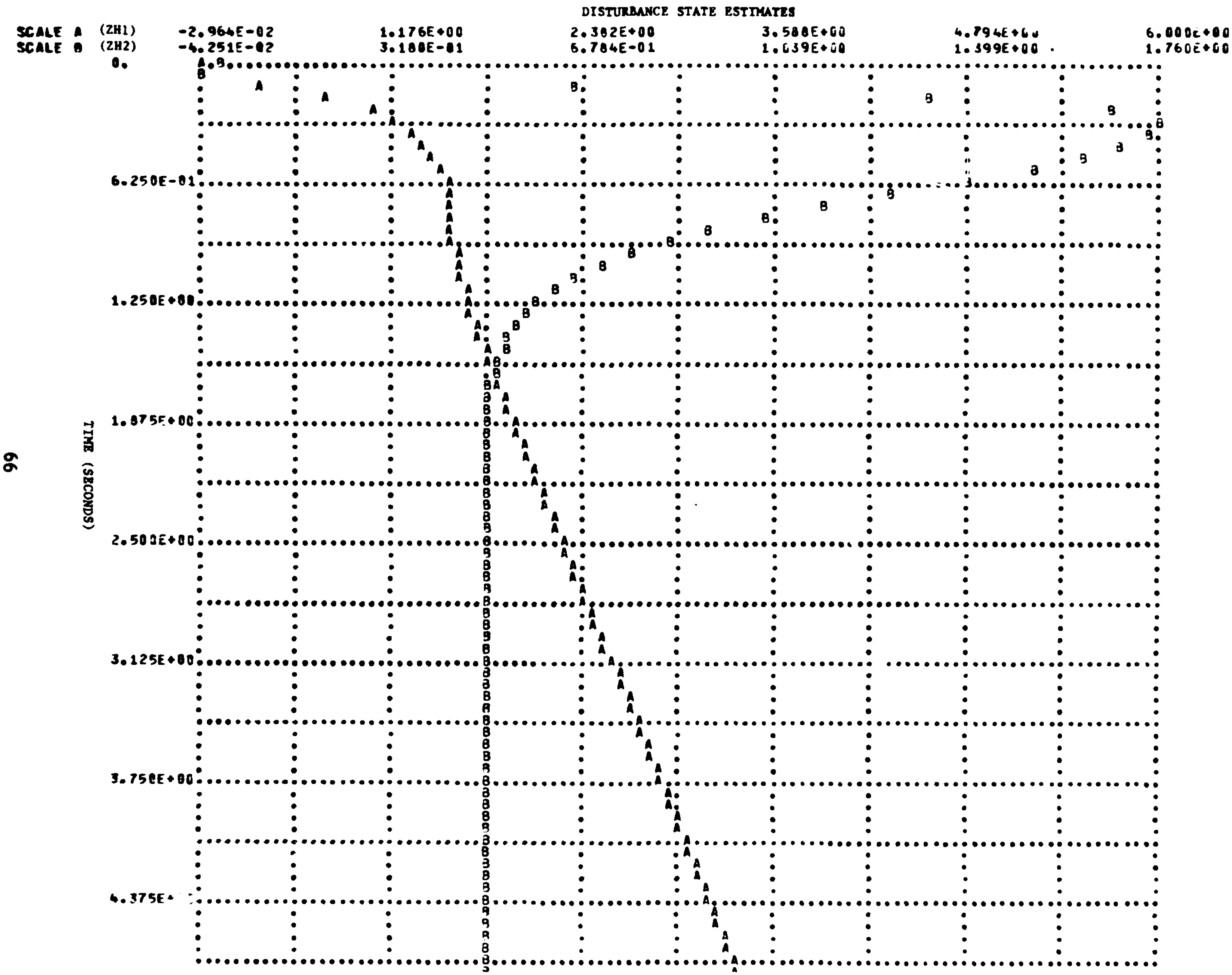
```
TIME =  .9000000E+01   XD1  =  .1612208E-05   XD2  =  .2617325E-04   XD3  =  .3575768E-03   XD4  =  .4699875E-03
X1   =  .8982460E+00   X2   =  .1589055E+02   X3   =  .2165745E+03   X4   =  .3545175E+03   XDH1 =  .1160746E-05
XDH2 =  .1320583E-04   XDH3 =  .2284290E-03   XDH4 =  .6141907E-05   ZDH1 =  .4999986E+00   ZDH2 = -.2590074E-05
XH1  =  .8982460E+00   XH2  =  .1589055E+02   XH3  =  .2165745E+03   XH4  =  .3545175E+03   ZH1  =  .5500000E+01
ZH2  =  .4999999E+00   PGO  =  .1000000E+01   W    =  .5500000E+01   UDA  =  .5500000E+01   Y    =  .8947430E+00

TIME =  .1000000E+02   XD1  = -.3262775E-06   XD2  = -.5578414E-05   XD3  = -.7649155E-04   XD4  = -.1650428E-03
X1   =  .8982462E+00   X2   =  .1589055E+02   X3   =  .2165746E+03   X4   =  .3545174E+03   XDH1 = -.2385754E-06
XDH2 = -.3120550E-05   XDH3 = -.5217440E-04   XDH4 = -.7554712E-04   ZDH1 =  .5000003E+00   ZDH2 =  .5032409E-06
XH1  =  .8982462E+00   XH2  =  .1589055E+02   XH3  =  .2165746E+03   XH4  =  .3545174E+03   ZH1  =  .6000000E+01
ZH2  =  .5000000E+00   PGO  =  .1000000E+01   W    =  .6000000E+01   UDA  =  .6000000E+01   Y    =  .8947433E+00

TIME =  .1000000E+02   XD1  = -.3262775E-06   XD2  = -.5578414E-05   XD3  = -.7649155E-04   XD4  = -.1650428E-03
X1   =  .8982462E+00   X2   =  .1589055E+02   X3   =  .2165746E+03   X4   =  .3545174E+03   XDH1 = -.2385754E-06
XDH2 = -.3120550E-05   XDH3 = -.5217440E-04   XDH4 = -.7554712E-04   ZDH1 =  .5000003E+00   ZDH2 =  .5032409E-06
XH1  =  .8982462E+00   XH2  =  .1589055E+02   XH3  =  .2165746E+03   XH4  =  .3545174E+03   ZH1  =  .6000000E+01
ZH2  =  .5000000E+00   PGO  =  .1000000E+01   W    =  .6000000E+01   UDA  =  .6000000E+01   Y    =  .8947433E+00
```


STEADY STATE OUTPUT LEVEL
WITH NO DISTURBANCE PRESENT
CURVE Y1 DENOTED BY A MIN= 0. MAX= 1.023E+00
SCALE A 0. 2.574E-02 2.252E-01 4.247E-01 6.242E-01 8.238E-01 1.023E+00
PLANT OUTPUT (Y)
6.250E-01
1.250E+00
1.875E+00
2.500E+00
3.125E+00
3.750E+00
4.375E+00
TIME (SECONDS)

CURVE Y1 DENOTED BY A   MIN=-2.964E-02 MAX= 6.000E+00
CURVE Y2 DENOTED BY B   MIN=-4.251E-02 MAX= 1.760E+00



RUN 3

```
$INP
ALP     = .25E+00,
A       = .2E+02, -.44E+03, -.108E+05, -.54E+05, .176816E+02, .243774E+03,     .4385048E+03, .2114116E+03,
BET     = .1E+01,
C       = -.3329E-01,
C0      = .15E+01,
C1      = .5E+00,
D       = 0.0, 0.0, .1E+01, .25E+00,
F       = .1E+01, 0.0,
LM      = (-.5E+01,0.0), (-.5E+01,0.0), (-.7E+01,.1E+02), (-.7E+01,-.1E+02),     (-.15E+02,0.0),
          (-.15E+02,0.0),
NFRT    = 16,
NUMBR   = 8,
NX      = 10,
PGO     = .1E+01,
STPSZ   = .32E+02,
TSTOP   = .2E+02,
$END
```

```
T(1)=-.440000E+02  0.          T(2)=-.370000E+02  -.100000E+02   T(3)=-.300000E+02  0.
T(4)=-.140000E+02  0.          T(5)=-.100000E+02  0.

A(1)=-.540000E+02 A(2)= .125900E+04 A(3)=-.166600E+05 A(4)= .129575E+06 A(5)=-.525750E+06 A(6)= .938125E+06

AM( 1)=-.332800E-01 AM( 2)=0.            AM( 3)=-.174316E+02 AM( 4)= .250000E+00 AM( 5)= .657280E+00
AM( 6)= .332800E-01 AM( 7)= .239354E+03 AM( 8)=0.           AM( 9)= .250000E+00 AM(10)=-.148096E+02
AM(11)= .665600E+00 AM(12)= .377561E+03 AM(13)=0.           AM(14)= .250000E+00 AM(15)=-.355763E+03
AM(16)=-.146432E+02 AM(17)= .101785E+03 AM(18)=0.           AM(19)= .250000E+00 AM(20)=-.170726E+04
AM(21)=-.359424E+03 AM(22)=-.528529E+02 AM(23)=0.           AM(24)= .449280E+03 AM(25)=-.179712E+04
AM(26)=0.

R(1)=-.365684E+02 R(2)= .101565E+04 R(3)= .162824E+05 R(4)= .129473E+06 R(5)= .525403E+06 R(6)= .938125E+06

XM(1,1)= .100000E+01 XM(1,2)=0.           XM(1,3)=0.           XM(1,4)=0.           XM(1,5)=-.332800E-01 XM(1,6)=0.
XM(2,1)= .250000E+00 XM(2,2)=-.100000E+01 XM(2,3)=0.           XM(2,4)=0.           XM(2,5)= .657280E+00 XM(2,6)= .332800E-01
XM(3,1)=0.           XM(3,2)= .250000E+00 XM(3,3)=-.100000E+01 XM(3,4)=0.           XM(3,5)=-.148096E+02 XM(3,6)= .665600E+00
XM(4,1)=0.           XM(4,2)=0.           XM(4,3)= .250000E+00 XM(4,4)=-.100000E+01 XM(4,5)=-.355763E+03 XM(4,6)=-.146432E+02
XM(5,1)=0.           XM(5,2)=0.           XM(5,3)=0.           XM(5,4)= .250000E+00 XM(5,5)=-.170726E+04 XM(5,6)=-.359424E+03
XM(6,1)=0.           XM(6,2)=0.           XM(6,3)=0.           XM(6,4)=0.           XM(6,5)= .449280E+03 XM(6,6)=-.179712E+04
XM(1,1)= .100000E+01 XM(1,2)=-.275441E-06 XM(1,3)=-.110176E-05 XM(1,4)=-.440706E-05 XM(1,5)=-.176282E-04 XM(1,6)= .356114E-05
XM(2,1)= .250001E+00 XM(2,2)=-.100001E+01 XM(2,3)=-.223107E-04 XM(2,4)=-.892429E-04 XM(2,5)=-.356972E-03 XM(2,6)= .535946E-04
XM(3,1)= .624701E-01 XM(3,2)=-.245880E+00 XM(3,3)=-.959521E+00 XM(3,4)= .191679E-02 XM(3,5)= .766718E-02 XM(3,6)=-.152387E-02
XM(4,1)= .148738E-01 XM(4,2)=-.594953E-01 XM(4,3)=-.237981E+00 XM(4,4)=-.951925E+00 XM(4,5)= .152302E+00 XM(4,6)=-.307532E-01
XM(5,1)= .206912E-05 XM(5,2)=-.827648E-05 XM(5,3)=-.331059E-04 XM(5,4)=-.132424E-03 XM(5,5)=-.529694E-03 XM(5,6)= .107005E-03
XM(6,1)= .517280E-06 XM(6,2)=-.206912E-05 XM(6,3)=-.827648E-05 XM(6,4)=-.331059E-04 XM(6,5)=-.132424E-03 XM(6,6)=-.529694E-03

   DET= -.3392748E+07   RA= .6000000E+01   E= 0.

K(1)=-.434415E+02 K(2)=-.118349E+04 K(3)=-.138646E+05 K(4)=-.518806E+05 K(5)=-.206524E+03 K(6)=-.518002E+03

   TIME = 0.             XD1  = -.1996800E+01   XD2  =  .439296CE+02   XD3  =  .1078272E+04   XD4  =  .5391360E+04
   X1   = 0.             X2   = 0.              X3   = 0.              X4   = 0.              XDF1 = -.2968623E+01
   XDH2 = -.5601700E+02  XDH3 = -.5488076E+03   XDH4 = -.1649016E+04   ZDH1 = -.1374622E+02   ZDH2 = -.3447922E+02
   XH1  = 0.             XH2  = 0.              XH3  = 0.              XH4  = 0.              ZH1  = 0.
   ZH2  = 0.             PGO  =  .1000000E+01   W    =  .2000000E+01   UDA  = 0.              Y    = -.9984000E-01
```

TIME =	.5000000E+00	XD1 =	.2653474E-01	XD2 =	.2167915E+01	XD3 =	-.6556425E+02	XD4 =	-.7163552E+03
X1 =	.4437170E+00	X2 =	.1497192E+02	X3 =	.2147379E+03	X4 =	.4157092E+03	XDH1 =	.1162827E-01
XDH2 =	.2661311E+01	XDH3 =	-.5032006E+02	XDH4 =	-.6064437E+03	ZDH1 =	-.6246437E-01	ZDH2 =	-.6359366E+01
XH1 =	.8720937E+00	XH2 =	.1603361E+02	XH3 =	.2260339E+03	XH4 =	.4561151E+03	ZH1 =	.2510634E+01
ZH2 =	.2746733E+01	FCC =	.1000000E+01	W =	.2066574E+01	UDA =	.2510634E+01	Y =	.8536357E+00

TIME =	.1000000E+01	XD1 =	.3697638E-01	XD2 =	.1000960E+01	XD3 =	.1120186E+02	XD4 =	.1073415E+03
X1 =	.7830443E+00	X2 =	.1369349E+02	X3 =	.1584369E+03	X4 =	.2979949E+03	XDH1 =	.2502802E-01
XDH2 =	.4690739E+00	XDH3 =	.4334606E+01	XDH4 =	.7794805E+02	ZDH1 =	-.1170431E+00	ZDH2 =	-.1431068E+01
XH1 =	.7884055E+00	XH2 =	.1411300E+02	XH3 =	.1511874E+03	XH4 =	.3086968E+03	ZH1 =	.2212788E+01
ZH2 =	.5037211E+00	FCC =	.1000000E+01	W =	.2140013E+01	UDA =	.2212788E+01	Y =	.7780107E+00

TIME =	.1500000E+01	XD1 =	.1572756E+00	XD2 =	.2085162E+01	XD3 =	.4225432E+02	XD4 =	.8133302E+02
X1 =	.8553521E+00	X2 =	.1528477E+02	X3 =	.2077866E+03	X4 =	.3628092E+03	XDH1 =	.1782951E+00
XDH2 =	.2978146E+01	XDH3 =	.4275185E+02	XDH4 =	.9104094E+02	ZDH1 =	.1767643E+00	ZDH2 =	-.3254230E-01
XH1 =	.8556717E+00	XH2 =	.1532665E+02	XH3 =	.2083525E+03	XH4 =	.3641771E+03	ZH1 =	.2232154E+01
ZH2 =	.2107443E+00	FCC =	.1000000E+01	W =	.2227496E+01	UDA =	.2232154E+01	Y =	.8505178E+00

TIME =	.2000000E+01	XD1 =	.7598750E-01	XD2 =	.4228396E+00	XD3 =	.6521887E+01	XD4 =	-.2647126E+02
X1 =	.9111736E+00	X2 =	.1615180E+02	X3 =	.2204168E+03	X4 =	.3719778E+03	XDH1 =	.4132667E-01
XDH2 =	.4838473E+00	XDH3 =	.7005097E+01	XDH4 =	-.2518115E+02	ZDH1 =	.2155716E+00	ZDH2 =	.6670283E-01
XH1 =	.5111440E+00	XH2 =	.1615772E+02	XH3 =	.2204713E+03	XH4 =	.3717478E+03	ZH1 =	.2324298E+01
ZH2 =	.2095989E+00	FCC =	.1000000E+01	W =	.2304361E+01	UDA =	.2324298E+01	Y =	.5081050E+00

TIME =	.2500000E+01	XD1 =	-.2473296E-01	XD2 =	-.4555841E+00	XD3 =	-.7309142E+01	XD4 =	-.2368020E+02
X1 =	.9090565E+00	X2 =	.1605719E+02	X3 =	.2190356E+03	X4 =	.3564092E+03	XDH1 =	-.2857676E-01
XDH2 =	-.5321597E+00	XDH3 =	-.7587465E+01	XDH4 =	-.2437010E+02	ZDH1 =	.2287046E+00	ZDH2 =	.4151143E-01
XH1 =	.9051059E+00	XH2 =	.1605465E+02	XH3 =	.2189665E+03	XH4 =	.3562741E+03	ZH1 =	.2434705E+01
ZH2 =	.2356415E+00	FCC =	.1000000E+01	W =	.2434123E+01	UDA =	.2434705E+01	Y =	.5055484E+00

TIME =	.3000000E+01	XD1 =	-.1168570E-01	XD2 =	-.1670953E+00	XD3 =	-.2714218E+01	XD4 =	.9961256E+00
X1 =	.8974926E+00	X2 =	.1586625E+02	X3 =	.2162224E+03	X4 =	.3513143E+03	XDH1 =	-.1350001E-01
XDH2 =	-.1943808E+00	XDH3 =	-.2821922E+01	XDH4 =	.5346734E+00	ZDH1 =	.2611459E+00	ZDH2 =	.5686083E-01
XH1 =	.8975195E+00	XH2 =	.1586504E+02	XH3 =	.2162076E+03	XH4 =	.3513535E+03	ZH1 =	.2558763E+01
ZH2 =	.2648814E+00	FCC =	.1000000E+01	W =	.2555800E+01	UDA =	.2558763E+01	Y =	.8539741E+00

TIME =	.3500000E+01	XD1 =	.2556802E-02	XD2 =	.6457784E-01	XD3 =	.1017406E+01	XD4 =	.5020504E+01
X1 =	.8958900E+00	X2 =	.1585198E+02	X3 =	.2160063E+03	X4 =	.3535618E+03	XDH1 =	.3469078E-02
XDH2 =	.7459258E-01	XDH3 =	.1074232E+01	XDH4 =	.5074153E+01	ZDH1 =	.3001726E+00	ZDH2 =	.7650946E-01
XH1 =	.8958948E+00	XH2 =	.1585232E+02	XH3 =	.2160141E+03	XH4 =	.3535579E+03	ZH1 =	.2655377E+01
ZH2 =	.2095233E+00	FCC =	.1000000E+01	W =	.2[illegible]478E+01	UDA =	.2699377E+01	Y =	.8523036E+00

TIME =	.4000000E+01	XD1 =	.2523702E-02	XD2 =	.4566276E-01	XD3 =	.7382021E+00	XD4 =	.6872096E+00
X1 =	.8575811E+00	X2 =	.1586867E+02	X3 =	.2165456E+03	X4 =	.3550052E+03	XDH1 =	.3351270E-02
XDH2 =	.5315770E-01	XDH3 =	.7706820E+00	XDH4 =	.7015742E+00	ZDH1 =	.3405517E+00	ZDH2 =	.8711554E-01
XH1 =	.8575747E+00	XH2 =	.1588[illegible]E+02	XH3 =	.216[illegible]E+03	XH4 =	.355[illegible]E+03	ZH1 =	.2855577E+01
ZH2 =	.3356759E+00	FCC =	.1000000E+01	W =	.2[illegible]41E+01	UDA =	.2859977E+01	Y =	.8544665E+00

```
X1    = .[illegible]       X2    = .[illegible]       X3    = .2165746E+03      X4    = .3545176E+03      XDH1 = .7653317E-05
XDH2  = .17[illegible]E-04 XDH3  = .[illegible]E-03   XDH4  = -.[illegible]     ZDH1  = .1044617E+01      ZDH2 = .2616661E+00
XH1   = .[illegible]       XH2   = .[illegible]       XH3   = .2165746E+03      XH4   = .3545177E+03      ZH1  = .5664449E+01
ZH2   = .174[illegible]    ROC   = .1000000E+01             = .[illegible]E+01  UDA   = .5664449E+01      Y    = .8947430E+00

TIME  = .[illegible]E+ 1   XD1   = -.7752[illegible]E-04   XD2   = -.[illegible]E-03   XD3   = -.1874798E-02   XD4  = -.5385958E-02
X1    = .[illegible]E+ 0   X2    = .1589076E+02      X3    = .2165746E+03      X4    = .3545176E+03      XDH1 = .1159796E-05
XDH2  = -.[illegible]E- 4  XDH3  = -.[illegible]E-03   XDH4  = -.[illegible]E-02   ZDH1  = .1195072E+01      ZDH2 = .2965047E+00
XH1   = .[illegible]E+ 0   XH2   = .1589056E+02      XH3   = .2165747E+03      XH4   = .3545177E+03      ZH1  = .6243668E+01
ZH2   = .118[illegible]E+ 1 ROC  = .1000000E+01             = .6243668E+01      UDA   = .6243668E+01      Y    = .8947438E+00

TIME  = .9500000E+ 1       XD1   = -.4317742E-04      XD2   = -.[illegible]E-03   XD3   = -.2253701E-02   XD4  = -.5685845E-02
X1    = .8982466E+00       X2    = .1589066E+02      X3    = .2165746E+03      X4    = .3545173E+03      XDH1 = .5592288E-06
XDH2  = -.4324226E-04      XDH3  = -.7004441E-03      XDH4  = -.[illegible]E-02   ZDH1  = .1743[illegible]E+01 ZDH2 = .3359[illegible]E+00
XH1   = .8982464E+ 0       XH2   = .1589055E+02      XH3   = .2165746E+03      XH4   = .3545174E+03      ZH1  = .6875[illegible]E+01
ZH2   = .1743877E+01       ROC   = .1000000E+01             = .6875[illegible]E+01 UDA = .6875[illegible]E+01 Y    = .8947436E+00

TIME  = .1000000E+02       XD1   = -.4[illegible]E-04  XD2   = -.755[illegible]E-03  XD3   = -.2428854E-02   XD4  = -.6026742E-02
X1    = .8982463E+00       X2    = .1589055E+02      X3    = .2165746E+03      X4    = .3545173E+03      XDH1 = .1120578E-05
XDH2  = -.3987864E-04      XDH3  = -.6620557E-03      XDH4  = -.[illegible]E-02   ZDH1  = .1522919E+01      ZDH2 = .3607192E+00
XH1   = .8982463E+00       XH2   = .1589055E+02      XH3   = .2165746E+03      XH4   = .3545174E+03      ZH1  = .7591247E+01
ZH2   = .1522812E+01       ROC   = .1000000E+01             = .7591247E+01      UDA   = .7591247E+01      Y    = .8947435E+00

TIME  = .1050000E+02       XD1   = -.5475[illegible]E-04 XD2  = -.8874422E-03      XD3   = -.2702917E-02   XD4  = -.6840739E-02
X1    = .8982463E+00       X2    = .1589055E+02      X3    = .2165746E+03      X4    = .3545173E+03      XDH1 = .1511594E-05
XDH2  = -.4167780E-04      XDH3  = -.6992875E-03      XDH4  = -.3623807E-02      ZDH1  = .1725590E+01      ZDH2 = .4314116E+00
XH1   = .8982463E+00       XH2   = .1589055E+02      XH3   = .2165746E+03      XH4   = .3545174E+03      ZH1  = .8402287E+01
ZH2   = .1725572E+01       ROC   = .1000000E+01             = .8402287E+01      UDA   = .8402287E+01      Y    = .8947435E+00

TIME  = .1100000E+02       XD1   = -.6209369E-04      XD2   = -.[illegible]E-03   XD3   = -.3079817E-02   XD4  = -.7835107E-02
X1    = .8982464E+00       X2    = .1589055E+02      X3    = .2165746E+03      X4    = .3545173E+03      XDH1 = .1655944E-05
XDH2  = -.4447503E-04      XDH3  = -.8103299E-03      XDH4  = -.4534601E-02      ZDH1  = .1955[illegible]E+01 ZDH2 = .4888574E+00
XH1   = .8982464E+00       XH2   = .1589055E+02      XH3   = .2165746E+03      XH4   = .3545175E+03      ZH1  = .9321716E+01
ZH2   = .1955329E+01       ROC   = .1000000E+01             = .9321716E+01      UDA   = .9321716E+01      Y    = .8947436E+00

TIME  = .1150000E+02       XD1   = -.7041313E-04      XD2   = -.1[illegible]E-02  XD3   = -.3502[illegible]E-02 XD4 = -.8856057E-02
X1    = .8982464E+00       X2    = .1589055E+02      X3    = .2165745E+03      X4    = .3545173E+03      XDH1 = .1916726E-05
XDH2  = -.5587282E-04      XDH3  = -.9318890E-03      XDH4  = -.5153419E-02      ZDH1  = .2215[illegible]E+01 ZDH2 = .5539434E+00
XH1   = .8982464E+00       XH2   = .1589055E+02      XH3   = .2165746E+03      XH4   = .3545176E+03      ZH1  = .1036271E+02
ZH2   = .2215678E+01       ROC   = .1000000E+01             = .1036271E+02      UDA   = .1036271E+02      Y    = .8947436E+00

TIME  = .1200000E+02       XD1   = -.7878760E-04      XD2   = -.1[illegible]E-02  XD3   = -.3968841E-02   XD4  = -.1006488E-01
X1    = .8982465E+00       X2    = .1589055E+02      X3    = .2165746E+03      X4    = .3545173E+03      XDH1 = .2[illegible]E-05
XDH2  = -.6322359E-04      XDH3  = -.1054713E-02      XDH4  = -.5[illegible]E-02  ZDH1  = .2510707E+01      ZDH2 = .6277001E+00
XH1   = .8982464E+00       XH2   = .1589055E+02      XH3   = .2165746E+03      XH4   = .3545175E+03      ZH1  = .1154277E+02
ZH2   = .2510[illegible]E+01 ROC = .1000000E+01             = .1154077E+02      UDA   = .1154077E+02      Y    = .8947437E+00

TIME  = .1250000E+02       XD1   = -.8840042E-04      XD2   = -.1[illegible]E-02  XD3   = -.4497710E-02   XD4  = -.1138861E-01
X1    = .8982465E+00       X2    = .1589055E+02      X3    = .2165746E+03      X4    = .3545173E+03      XDH1 = .2346231E-05
XDH2  = -.7143267E-04      XDH3  = -.1192116E-02      XDH4  = -.[illegible]E-02   ZDH1  = .2845[illegible]E+01 ZDH2 = .7112774E+00
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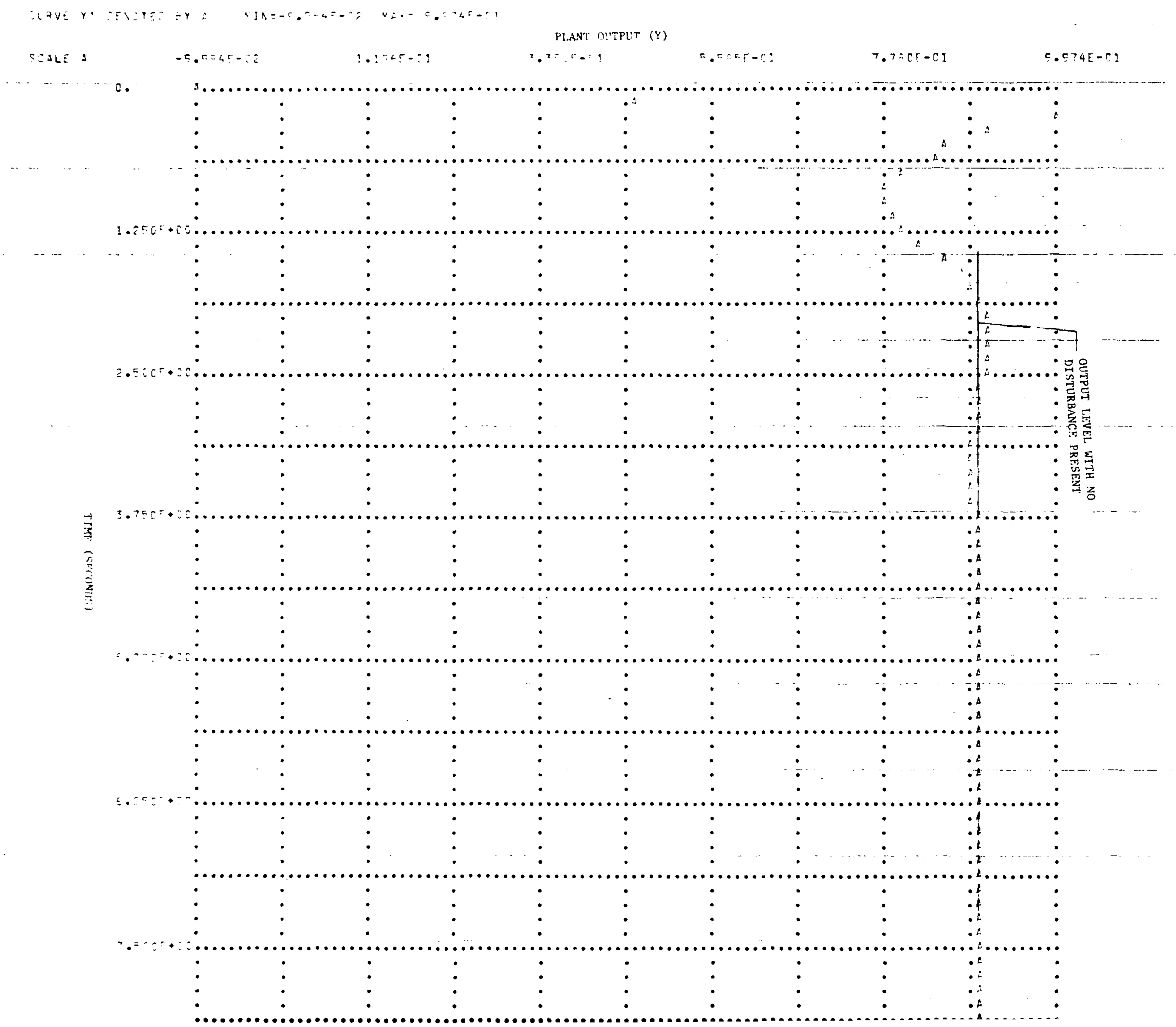
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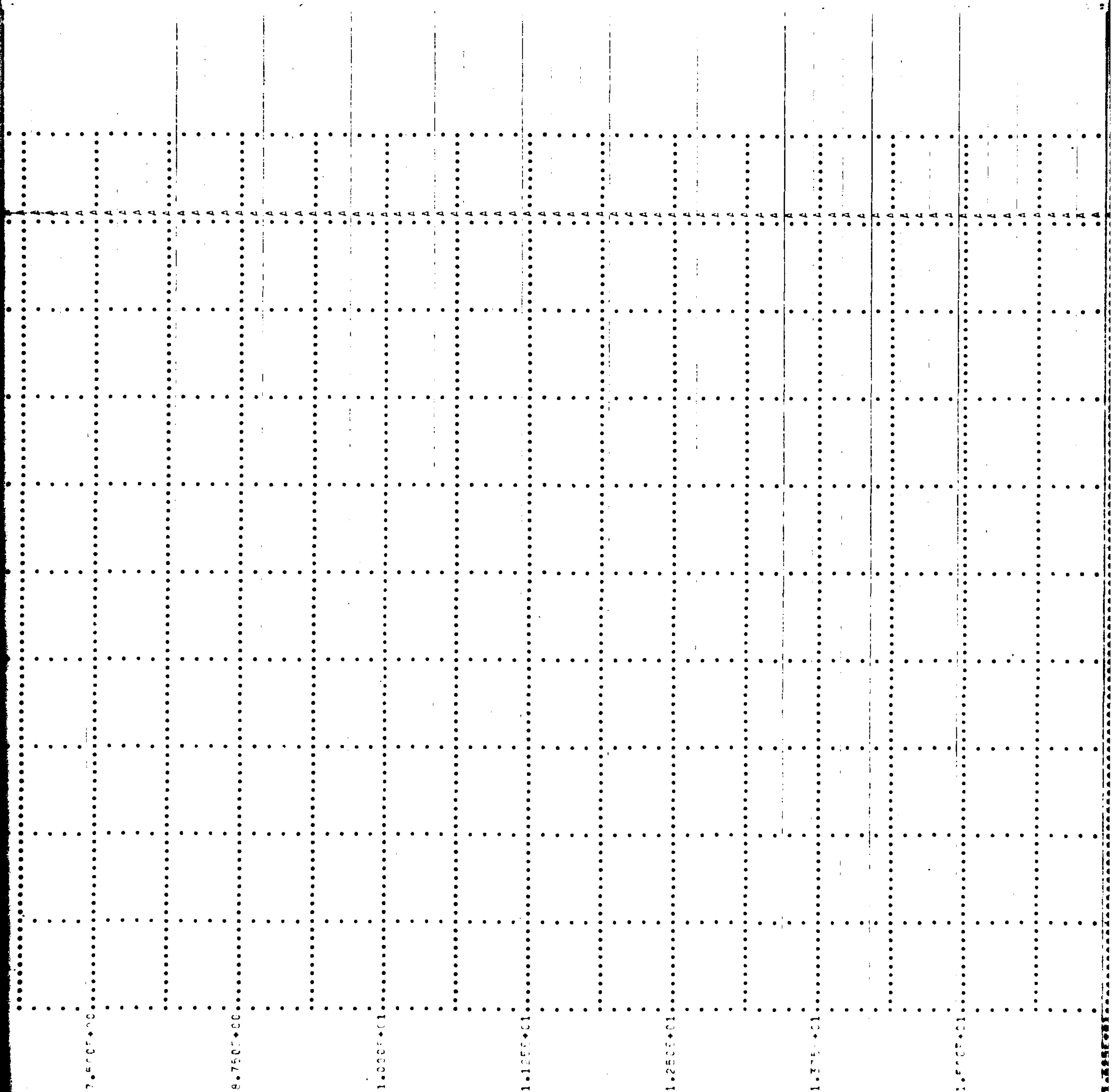
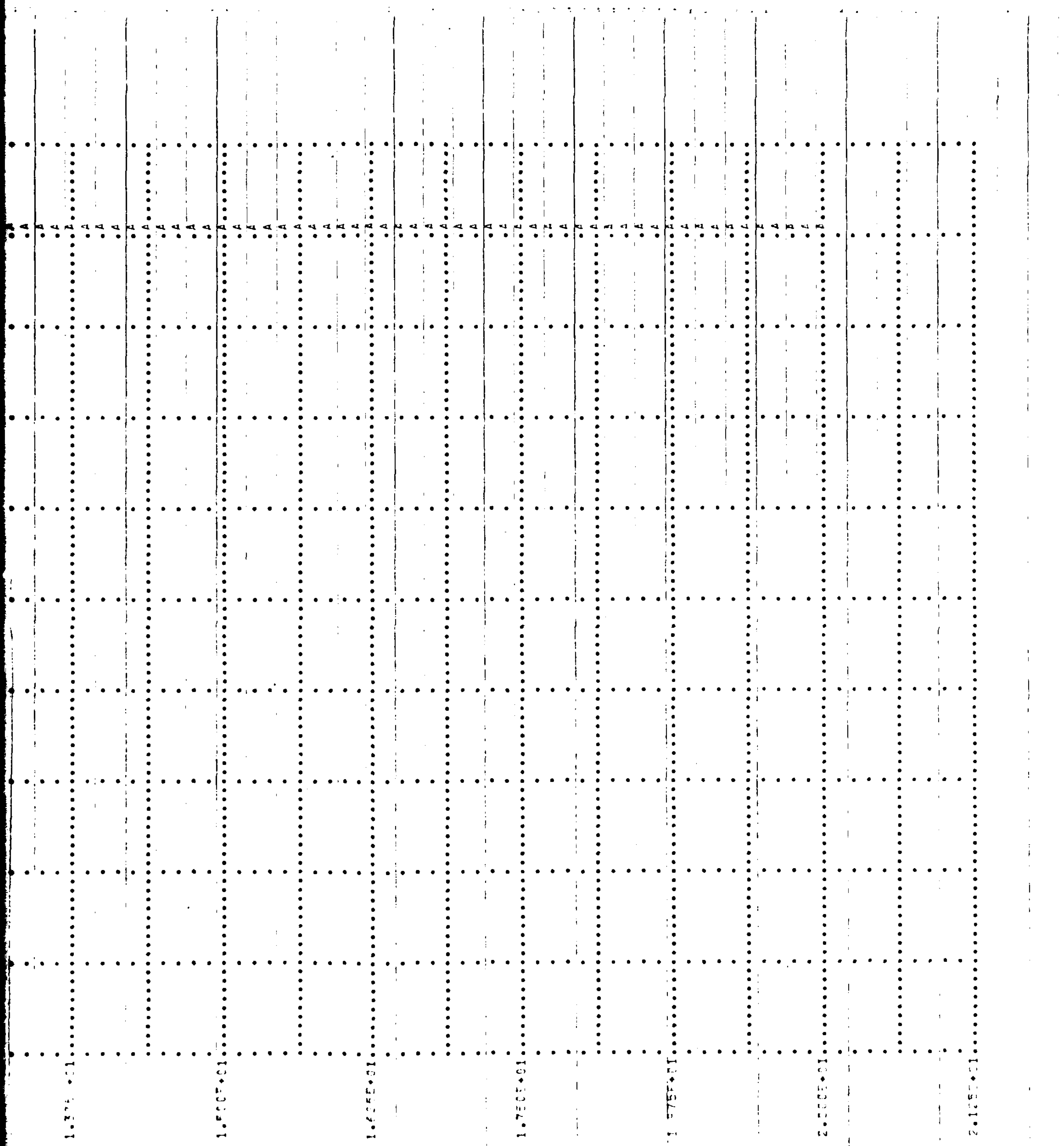
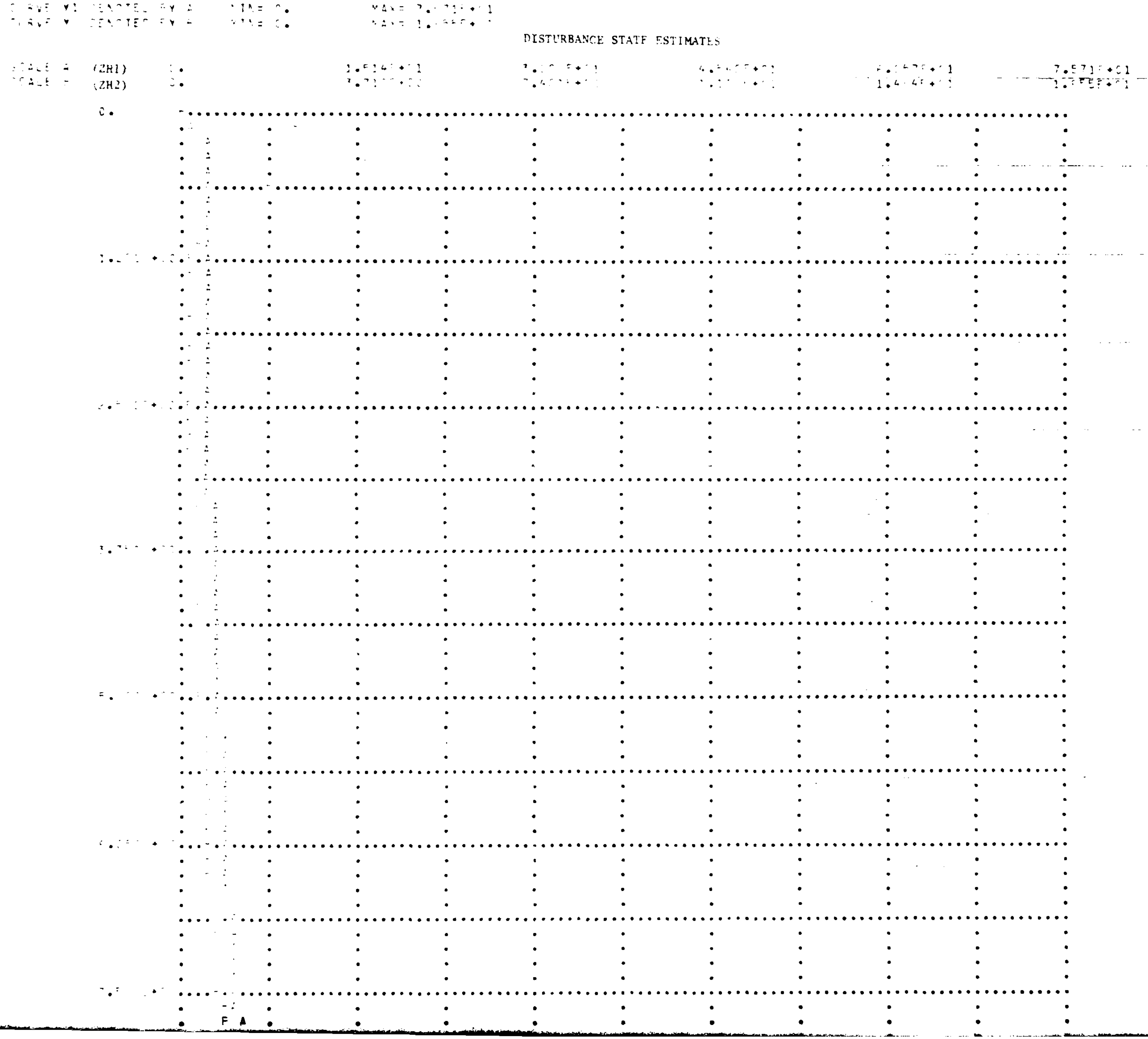
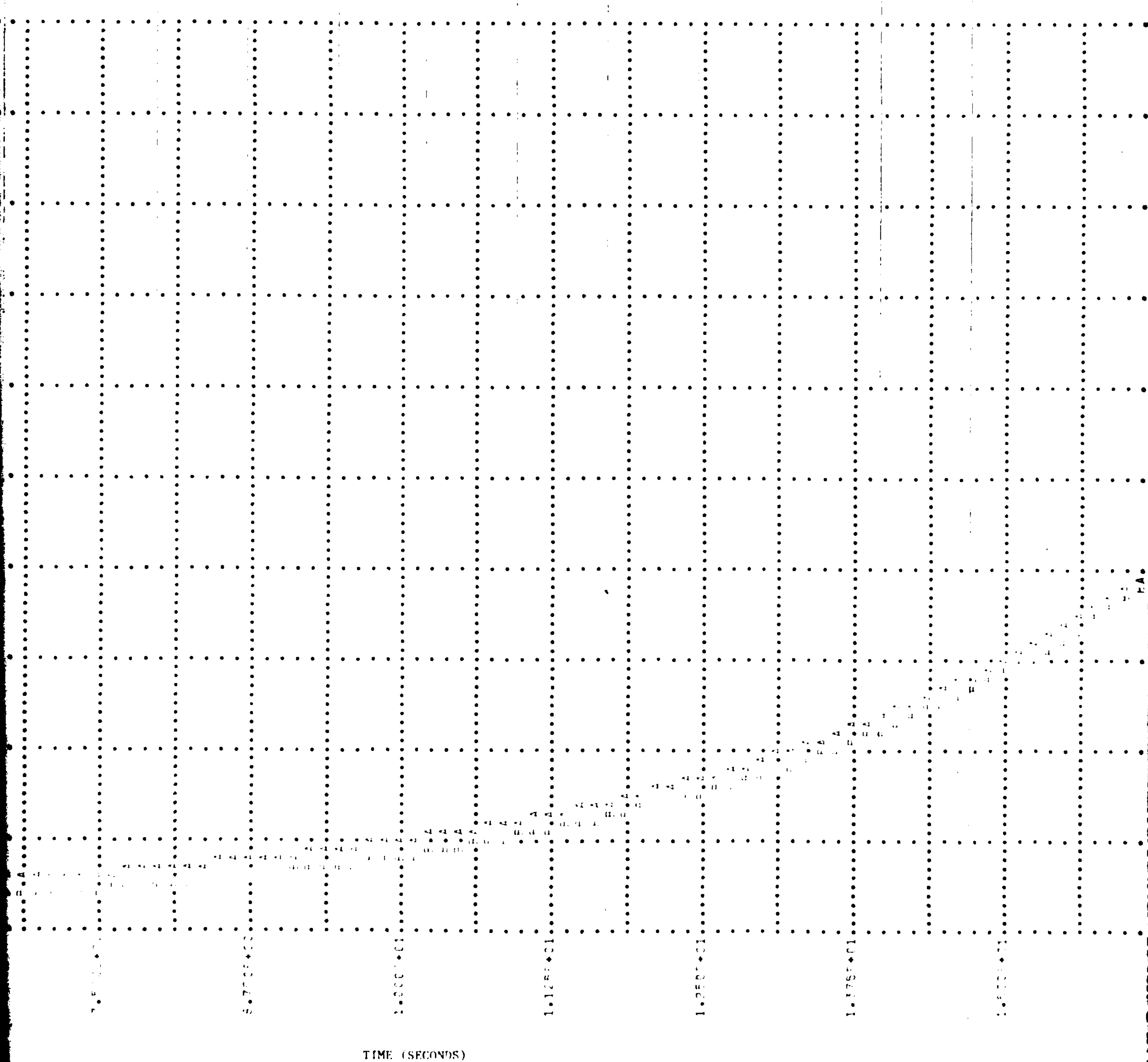
TIME (SECONDS)
OUTPUT LEVEL WITH NO DISTURBANCE PRESENT





DISTURBANCE STATE ESTIMATES

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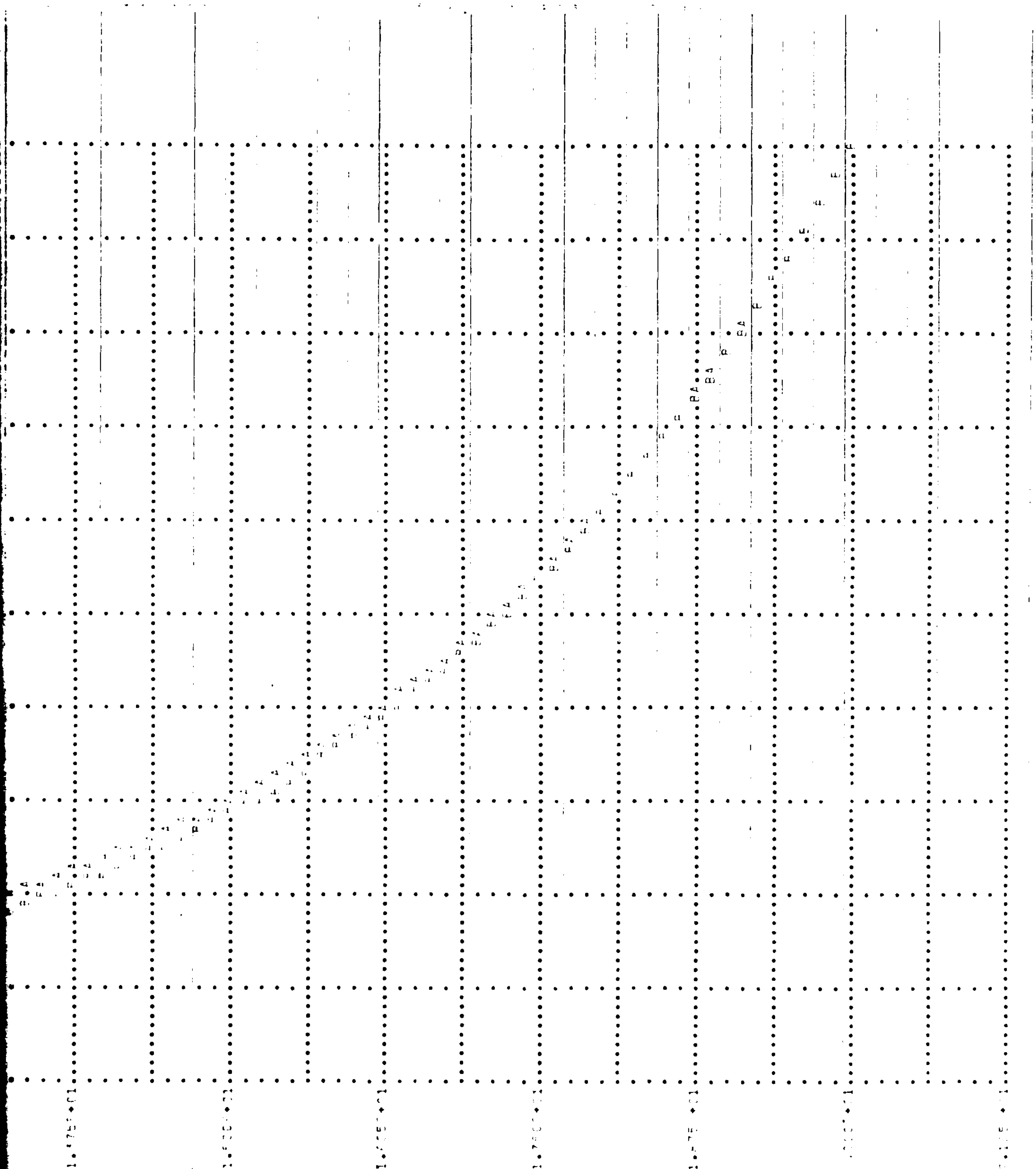

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